OAIP
Ontario
Assessment
Instrument
Pool

Physics

PACKAGE III

SENIOR DIVISION

Ontario
Ministry
of
Education

Hon. Bette Stephenson, M.D., Minister
Harry K. Fisher, Deputy Minister

PHYSICS: Package III

SENIOR DIVISION

THE ONTARIO ASSESSMENT INSTRUMENT POOL

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This package contains a representative sample of created response instruments: short answer, completion, essay, and problem instruments. Some selected response matching exercises are also included. Some of the instruments can be used in evaluating the aims, goals, and objectives of Senior Division Physics, some at the Ontario Academic Credit Level, and some at both levels. The package also includes the scoring policy and an answer and scoring scheme for each instrument.

Cost: $15.00

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Scoring Created Response Instruments

The scoring of created response instruments involves a number of subjective judgments on the part of the scorer. These subjective judgments are minimized and the scoring is more reliable if a detailed scoring scheme is followed. A scoring scheme has been provided for each created response instrument in the OAIP: Physics.

The scoring policy adopted for OAIP: Physics is that of 'a point for a point'. One scoring point is awarded for each clearly identifiable step or element which makes an essential contribution to a correct and complete answer. An element is scored either '√' or 0; that is, an element is either there or it isn't and is credited or not credited accordingly.

The details of the scoring policy adopted for created response instruments is summarized below. A '√' indicates that a scoring point is awarded for the element indicated. The teacher should use discretion in the use of the scoring policy.

Scoring Policy Adopted for Created Response Instruments

Setting up the Problem

√ extraction of relevant data (including units and assignment of data to the correct variable)
√ statement of convention (e.g. take downward as positive)
√ listing of implied or assumed values (e.g. $v_i = 0$, $a = g$)
√ statement of relevant general principles or laws
√ drawing of a sketch showing the situation and the objects (e.g. projectile thrown from building)

Equations

√ choice of relevant equation (e.g. $F = ma$)
√ correct substitution of data into the equation

Mathematical Computation

√ re-arranging the variables in an equation to isolate the unknown (either before or after substitution)
√ performing key steps needed to obtain the final answer such as obtaining the value of a constant from tables or a calculator, simplification, factoring, or applying a mathematical identity

Final Answer

✓ magnitude (numeral and exponent)
✓ unit
✓ direction (when applicable)
✓ sign (when appropriate) (e.g. gain or loss of energy)
✓ number of significant figures (when appropriate)
✓ final statement (answer to the question)

Special Considerations

(i) Free Body Diagrams

✓ each correctly labelled vector

(ii) Vector Sketches

for each correct vector

✓ label (e.g. v(a/g))
✓ magnitude where appropriate (e.g. 400 m/s)
✓ direction where appropriate (e.g. [N])
✓ orientation with reference to other vectors (e.g. head to tail, tail to tail, etc.)

(iii) Vector Scale Diagrams

✓ indication of scale
✓ appropriateness of scale
✓ constructed length of each given vector
✓ constructed direction of each given vector
✓ length of each measured vector
✓ determination of the true length of each measured vector
✓ direction of each measured vector ✓(using scale)

(iv) Sketched Graphs

✓ correct shape
✓ correct placement with reference to origin
✓ correct slope at key locations (e.g. origin)

(v) Plotted Graphs

✓✓ appropriateness of title
✓✓ assignment of variables to axes
✓✓ labelling quantities on axes
✓✓ labelling units on axes
✓✓✓✓ appropriateness of axes scales
✓✓✓✓ accuracy of plotted points
✓✓ appropriateness of indication of plotted points (error bars)
✓✓✓✓ appropriateness of line of best fit
✓✓✓ neatness

NOTE: 1. See the Scoring Scheme for Graphs on page 39.
2. Allocate the tick '✓' marks indicated, sum, and divide by 5 to achieve a realistic weighting.

(vi) Ray Diagrams

√ each appropriate ray
√ each correct arrowhead
√ each appropriate angle
√ each characteristic of the image

Guidelines for Implementing the Scoring Policy

1. Students should be encouraged to substitute units with numerals into equations and to carry units throughout the solution of a problem. Physical quantities, such as mass, force, and momentum, are completely described only when units are included with numerals. The substitution of units has several merits: it provides a check on the accuracy of the equation; it points out the need for consistent units; and it identifies the unit of the answer. Students should not be penalized if units are dropped part way through the solution of a problem. Some units are cumbersome to carry. But if units are dropped, students should write 'units dropped' as a signal to the scorer of a conscious decision to do so.

2. Mathematical computations should not take precedence over the physics in a question. Accordingly, a minimum of points has been allotted for arithmetical manipulation. For this reason the use of calculators in created response instruments is optional.

3. A mechanical error should result only in the loss of marks for the step in which the error occurred. The examiner should trace the solution through to the final answer without deducting further marks unless additional errors are made.

4. Students should be encouraged to show their complete solution to a problem. However full marks are assigned to the correct answer even if intermediate steps are omitted provided the logic is sound.

5. The final answer to all created response instruments should be in the form of a statement. This statement is an answer to the question asked in the problem.

MEASUREMENT

1 NOTE: Do not permit the use of calculators for this series of diagnostic problems.

S17A
I.1.d For items 1-8, reduce the expression to its simplest
S17C form and place your answer in the space provided.
I.1.d Express your answer in scientific notation (standard form).

1

	Scoring Scheme				Answer
F1					
A4					
A7	✓	(1)	$10^4 \times 10^{-7}$	= ______	(10^{-3})
*	✓	(2)	$10^{-5} \div 10^2$	= ______	(10^{-7})
*					
*	✓	(3)	$10^{-2} \times 10^{-15}$	= ______	(10^{-17})
	✓ ✓ ✓	(4)	$\dfrac{3.6 \times 10^7}{12 \times 10^{-2}}$	= ______	(3.0×10^8) or (0.3×10^9)
	✓ ✓	(5)	$\dfrac{2.5 \times 10^{-3}}{5.0 \times 10^2}$	= ______	(5.0×10^{-6})
	✓ ✓	(6)	$\dfrac{28\ \text{m/s} - 5.0\ \text{m/s}}{10\ \text{s}}$	= ______	$(2.3\ \text{m/s}^2)$
	✓ ✓	(7)	$\dfrac{29\ \text{m/s} - 9\ \text{m/s}}{5.0\ \text{s}}$	= ______	$(4.0\ \text{m/s}^2)$
	✓ ✓	(8)	$\dfrac{32\ \text{m/s} - 40\ \text{m/s}}{4.0\ \text{s}}$	= ______	$(-2\ \text{m/s}^2)$

2 For items 1-6, express the measurement in scientific notation (standard form) to two significant figures.

S17A
I.1.d Scor-
S17C ing
I.1.d <u>Scheme</u>

	Scoring Scheme						Answer
1	✓ ✓	(1)	37 005 m	=	________	m	(3.7×10^4 m)
A4	✓ ✓	(2)	0.028 cm	=	________	cm	(2.8×10^{-2} cm)
* *	✓ ✓	(3)	570 m	=	________	m	(5.7×10^2 m)
*	✓ ✓	(4)	0.003 14 s	=	________	s	(3.1×10^{-3} s)
	✓ ✓	(5)	22 m	=	________	m	(2.2×10^1 m)
	✓ ✓	(6)	0.004 270 g	=	________	g	(4.3×10^{-3} g)

3

S17A
I.1.a
S17C
I.1.d

NOTE: Do not permit the use of calculators for this series of diagnostic problems. The objective is to test understanding of the laws of exponents. These are pure numbers not measured quantities. Any mathematically correct answer is acceptable.

S1

A7
F1
A4

For items 1-14, simplify the expression and place your answer using power of ten notation in the space provided.

*
*
**

Scoring Scheme				Answer
√	(1)	$10^4 \times 10^6$	= ______________	(10^{10})
√	(2)	$10^7 \times 10^{-3}$	= ______________	(10^4)
√	(3)	$10^{-5} \times 10^5$	= ______________	(10^0 or 1)
√	(4)	$10^{-5} \times 10^{-5}$	= ______________	(10^{-10})
√	(5)	$10^6 \div 10^4$	= ______________	(10^2)
√	(6)	$10^4 \div 10^6$	= ______________	(10^{-2})
√	(7)	$10^8 \div 10^4$	= ______________	(10^4)
√	(8)	$10^8 \div 10^{-5}$	= ______________	(10^{13})
√	(9)	$10^7 \div 10^7$	= ______________	(10^0 or 1)
√	(10)	$10^7 \div 10^{-7}$	= ______________	(10^{14})
√	(11)	$10^{-7} \div 10^{-7}$	= ______________	(10^0 or 1)
√	(12)	$10^{-7} \div 10^7$	= ______________	(10^{-14})
√	(13)	$(10^6)^2$	= ______________	(10^{12})
√	(14)	$\sqrt{10^{10}}$	= ______________	(10^5)

4

S17A
I.1.a
S17C
I.1.d

NOTE: Do not permit the use of calculators for this series of diagnostic problems. The objective is to test understanding of the laws of exponents. These are pure numbers, not measured quantities. Any mathematically correct answer is acceptable.

S1

A7
F1
A4

For items 1-9, simplify the expression and place your answer using power of ten notation in the space provided.

Scoring Scheme		Expression			Answer
*					
* ✓ ✓	(1)	$10^5 + 10^6$	=	________	(1.1×10^6)
**					
✓ ✓	(2)	$10^5 - 10^4$	=	________	(9×10^4)
✓ ✓	(3)	$10^3 - 10^4$	=	________	(-9×10^3)
✓ ✓	(4)	$5.0 \times 10^5 + 4.0 \times 10^5$	=	________	(9.0×10^5)
✓ ✓	(5)	$7.0 \times 10^4 - 3.2 \times 10^4$	=	________	(3.8×10^4)
✓ ✓	(6)	$2.0 \times 10^6 + 3.0 \times 10^5$	=	________	(2.3×10^6)
✓ ✓	(7)	$2.0 \times 10^5 + 3.0 \times 10^6$	=	________	(3.2×10^6)
✓ ✓	(8)	$5.1 \times 10^6 - 1.0 \times 10^5$	=	________	(5.0×10^6)
✓ ✓	(9)	$4.0 \times 10^5 - 7.5 \times 10^6$	=	________	(-7.1×10^6)

5

S17A
I.1.a
S17C
I.1.d

NOTE: Do not permit the use of calculators for this series of diagnostic problems. The objective is to test understanding of the laws of exponents. These are pure numbers, not measured quantities. Any mathematically correct answer is acceptable.

S1

For items 1-12, simplify the expression and place your answer using power of ten notation in the space provided.

A7
F1
A4

Scoring Scheme		Expression			Answer
*					
* ✓ ✓	(1)	$(3.0 \times 10^4) \times (2.0 \times 10^4)$	=	________	(6.0×10^8)
**					
✓ ✓	(2)	$(2.0 \times 10^4) \times (3.0 \times 10^3)$	=	________	(6.0×10^7)
✓ ✓	(3)	$(5.0 \times 10^3) \times (1.2 \times 10^{-3})$	=	________	(6.0)
✓ ✓	(4)	$(3.0 \times 10^4) \div (2.0 \times 10^4)$	=	________	(1.5)
✓ ✓	(5)	$(3.0 \times 10^4) \div (6.0 \times 10^3)$	=	________	(5.0)
✓ ✓	(6)	$(6.0 \times 10^3) \div (5.0 \times 10^{-3})$	=	________	(1.2×10^6)
✓ ✓	(7)	$(3.0 \times 10^4)^2$	=	________	(9.0×10^8)
✓ ✓	(8)	$(2.0 \times 10^{-3})^3$	=	________	(8.0×10^{-9})
✓ ✓	(9)	$\sqrt{16 \times 10^{10}}$	=	________	(4.0×10^5)
✓ ✓ ✓	(10)	$\sqrt{640 \times 10^9}$	=	________	(8.0×10^5)
✓ ✓	(11)	$\sqrt{49 \times 10^{-8}}$	=	________	(7.0×10^{-4})
✓ ✓ ✓	(12)	$\sqrt{6.4 \times 10^7}$	=	________	(8.0×10^3)

6

S17A
I.1.d

3

A4

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Calculate the area of one surface of a thin ribbon of metal that is measured to be 2.0 cm wide and 2 467 cm long.

Express your answer to the correct number of significant digits.

Scoring Scheme	Answer
	$w = 2.0$ cm
✓	
	$l = 2\ 467$ cm
✓	$A = l\,w$
✓	$= 2.0 \text{ cm} \times 2\ 467 \text{ cm}$
✓ ✓	$= 4\ 934 \text{ cm}^2$
✓	$= 4.9 \times 10^3 \text{ cm}^2$
✓	The area of one surface of the ribbon is $4.9 \times 10^3 \text{ cm}^2$.

7

S17A
I.1.c
S17C
I.1.a

For items 1-10, perform the conversion indicated and place your answer in the space provided. Ignore significant figures in your answer.

4

A4

**

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Scoring Scheme				Answer		
√	(1)	7 766 g	=	________	kg	(7.766)
√	(2)	0.009 m	=	________	mm	(9)
√	(3)	0.004 ms	=	________	μs	(4)
√	(4)	246 000 kg	=	________	Mg	(246)
√	(5)	4.7×10^{-6} g	=	________	μg	(4.7)
√	(6)	3.2×10^{4} m	=	________	km	(32)
√	(7)	11 000 μs	=	________	cs	(1.1)
√	(8)	534 dm	=	________	dam	(5.34)
√	(9)	0.0035 hg	=	________	g	(0.35)
√	(10)	100 das	=	________	ks	(1)

8 For items 1-9, place your answer in the space provided.

	Scoring Scheme				Answer
S17A I.1.a S17C I.2.b					
SS 4	√	(1)	If A = BC, then B =	____________	(A/C)
A7 F1	√	(2)	If C = B/A, then B =	____________	(AC)
	√	(3)	If A = B/C, then C =	____________	(B/A)
* * *	√	(4)	If A = B + C, then B =	____________	(A - C)
	√	(5)	If A = B + C, then C =	____________	(A - B)
	√	(6)	If C = B - A, then B =	____________	(A + C)
	√	(7)	If C = B - A, then A =	____________	(B - C)
	√	(8)	If A = B + CD, then B =	____________	(A - CD)
	√ √	(9)	If A = B + CD, then C =	____________	$\left(\frac{A - B}{D}\right)$

9 For items 1-7, place your answer in the space provided.

S17A I.1.a S17C I.2.b

SS 4

A7 F1

* * *

Scoring Scheme			Answer	
√ √	(1)	If $A = \frac{B + C}{D}$, then B =	______________	$(AD - C)$
√ √	(2)	If $A = \frac{B + C}{D}$, then D =	______________	$(\frac{B + C}{A})$
√ √	(3)	If $B = \frac{A - D}{C}$, then A =	______________	$(BC + D)$
√ √ √	(4)	If $B = \frac{A - D}{C}$, then D =	______________	$(A - BC)$
√ √	(5)	If $B = \frac{A - D}{C}$, then C =	______________	$(\frac{A - D}{B})$
√	(6)	If $A = C - BD$, then C =	______________	$(A + BD)$
√ √ √	(7)	If $A = C - BD$, then D =	______________	$(\frac{C - A}{B})$

10 For items 1-5, place your answer in the space provided.

S17A I.1.a S17C I.2.b	Scoring Scheme				Answer
	✓	(1)	If $A = BC^2$, then $B =$	________	(A/C^2)
SS 4	✓ ✓	(2)	If $A = BC^2$, then $C =$	________	$(\pm\sqrt{\frac{A}{B}})$
A7 F1	✓ ✓	(3)	If $A = \frac{BD^2}{C}$, then $B =$	________	$(\frac{AC}{D^2})$
* * *	✓	(4)	If $A = \frac{BD^2}{C}$, then $C =$	________	$(\frac{BD^2}{A})$
	✓ ✓ ✓	(5)	If $A = \frac{BD^2}{C}$, then $D =$	________	$(\pm\sqrt{\frac{AC}{B}})$

11 Consider the equation $R = -qT$.

S17A
I.1.a
S17C
I.2.b

SS 4

F1
A7

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*
*

(a) If $R = 3$ and $T = 9$, the value of q is ______.

(b) If $R = 12$ and $q = 6$, the value of T is ______.

Scoring Scheme	Answer
✓ ✓	(a) $q = -1/3$
✓ ✓	(b) $T = -2$

12

S17A
I.1.a
S17C
I.2.b

SS 4

F1
A7

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Consider the equation $R = -qT$.

(a) If $R = 9$ and $T = 3$, the value of q is ________.

(b) If $R = 12$ and $q = 4$, the value of T is ________.

Scoring Scheme	Answer
✓ ✓	(a) $q = -3$
✓ ✓	(b) $T = -3$

13 Consider the equation $R = -qT$.

S17A
I.1.a
S17C
I.2.b

(a) Solve this equation for q. ____________

(b) Solve this equation for T. ____________

SS 4

F1
A7

*
*
*

Scoring Scheme	Answer
✓ ✓	(a) $q = \frac{-R}{T}$
✓ ✓	(b) $T = \frac{-R}{q}$

FUNCTIONS

1

S17C
III.6.a

11

D3
A11
F1

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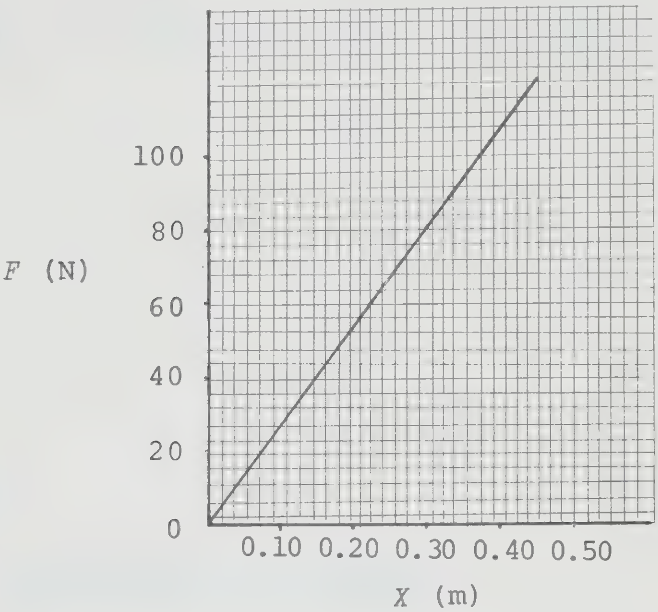
*
-

The following graph illustrates the force F, exerted by a spring, versus the compression X.



(a) Write the proportionality statement relating F and X.

(b) Determine the specific equation relating F and X.

Scoring Scheme	Answer
✓	(a) $F \propto X$
✓	(b) $F = kX$
✓	$k = \dfrac{\text{rise}}{\text{run}}$
✓ ✓	$= \dfrac{(80 - 0)\ \text{N}}{(0.30 - 0)\ \text{m}}$
	$= 267$ N/m
✓ ✓	$= 2.7 \times 10^2$ N/m
✓	$\therefore F = (2.7 \times 10^2\ \text{N/m})X$

2

S17C
I.2.b

11
12

A11

*
*
-

Consider the equation $a = \frac{kbc^2}{d^2}$, where k is a positive constant. Write the proportionality statement (in symbols or words) for:

(a) the relationship between a and b, when c and d are constant

(b) the relationship between a and c, when b and d are constant

(c) the relationship between a and d, when b and c are constant

Scoring Scheme	Answer
✓	(a) $a \propto b$, or a is (directly) proportional to b
✓	(b) $a \propto c^2$, or a is (directly) proportional to c^2
✓	(c) $a \propto \frac{1}{d^2}$, or a is inversely proportional to d^2

3

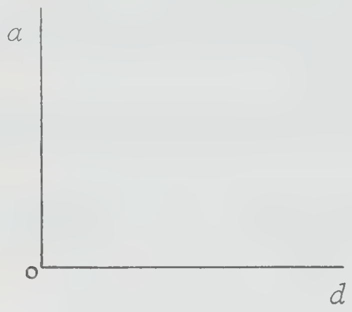
S17C
I.2.b

11
12

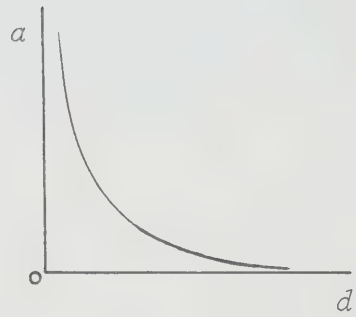
All

-
*
-

Using the axes provided, sketch (do not plot) the first quadrant portion of the graph of the relationship between a and d when $a = k/d^2$, where k is a positive constant.



Scoring Scheme	Answer
√	correct shape
√	asymptotic to axes



4

S17C
I.2.b

11
12

All

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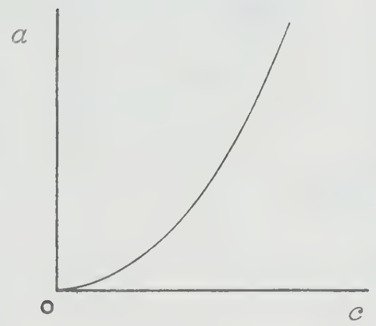
*
-

Using the axes provided, sketch (do not plot) the first quadrant portion of the graph of the relationship between a and c when $a = kc^2$, where k is a positive constant.

Scoring Scheme	Answer
✓	correct shape
✓	passing through the origin
✓	slope zero at origin



5

S17C
I.2.b

S 11

A11
A7

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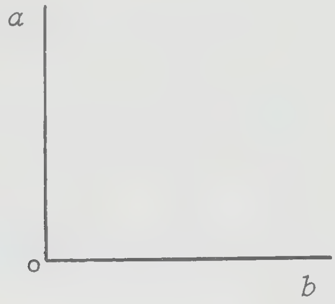
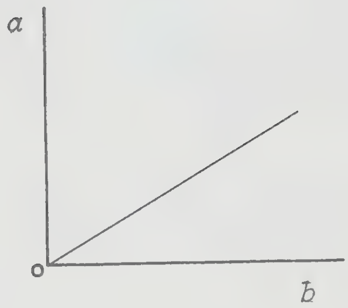
Using the axes provided, sketch (do not plot) the first quadrant portion of the graph of the relationship between a and b when $a = kb$, where k is a positive constant.



Scoring Scheme	Answer
✓ correct shape ✓ passing through the origin	

6 Consider the following statement:

S17C
I.2.b

"r is directly proportional to the sum of s and t, and is inversely proportional to the square of y".

12

Write the general corresponding equation for r in terms of s, t, and y.

All

*
*
-

Scoring Scheme	Answer
	$r = \frac{k\,(s + t)}{y^2}$
√	correct interpretation of direct proportion to sum
√	correct interpretation of inverse proportionality
√	constant and equality sign
√	correct use of brackets

7 Consider the equation $P = \frac{1}{4}SY^2$.

S17A
I.1
S17C
I.2.b

SS 12

F1
A7

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*
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(a) Solve the equation for S.

(b) Solve the equation for Y.

Scoring Scheme	Answer
✓ ✓	(a) $S = \frac{4P}{Y^2}$
✓✓✓✓	(b) $Y = \pm\sqrt{\frac{4P}{S}}$ <u>or</u> $\pm 2\sqrt{\frac{P}{S}}$

K I N E M A T I C S

MOTION IN A STRAIGHT LINE

1

S17A
I.2.a
S17C
I.3.a

For items 1-5, determine the <u>slope</u> of each graph and place your answer in the space provided. Include the correct SI units, but do <u>not</u> be concerned about significant digits.

S 15 Scoring Scheme

Answer

F1
A11
A7

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*
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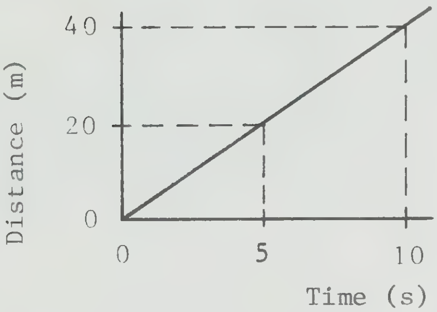
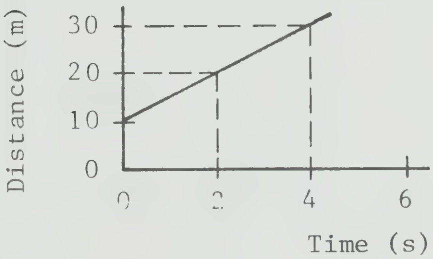
√ √ (1)



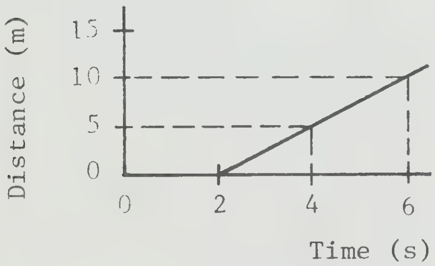
__________ (4 m/s)

√ √ (2)



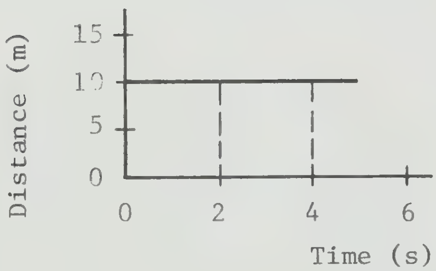
__________ (5 m/s)

√ √ (3)



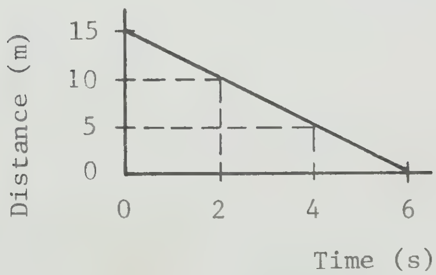
__________ (2.5 m/s)

√ √ (4)



__________ (0)

√ √ √ (5)



__________ (-2.5 m/s)

2 The slope of a position-time graph gives a quantity called ______________.

S17A
I.2.a
S17C
I.3.a

16

A3
A7

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Scoring Scheme	Answer
√	velocity

3

S17A
I.2.a
S17C
I.3.a

16

A11
A7

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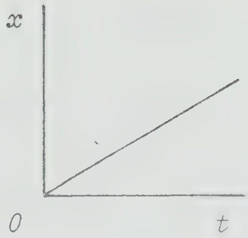
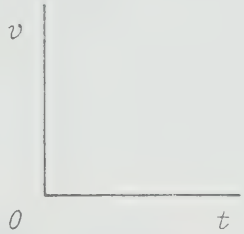
**

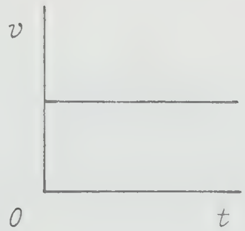
The position-time graph for an object travelling in a straight line is shown.



Using the axes provided, sketch the shape of the velocity-time graph for the object's motion.



Scoring Scheme	Answer
√	position of line above origin
√	straight line with zero slope



4 The slope of a velocity-time graph gives a quantity called ____________.

S17A
I.2.a
S17C
I.3.b

17

A3
A7

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Scoring Scheme	Answer
✓	acceleration

5

S17A
I.2.a
S17C
I.3.b

17
15

A7
A11

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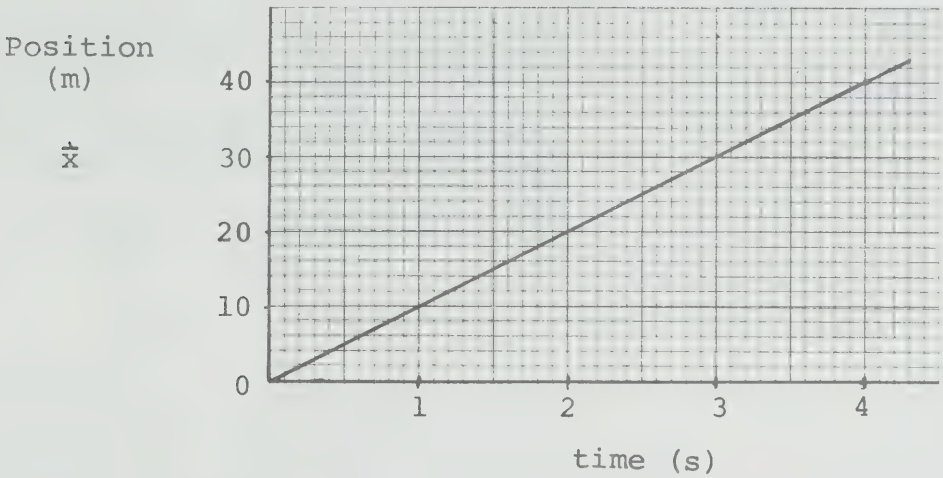
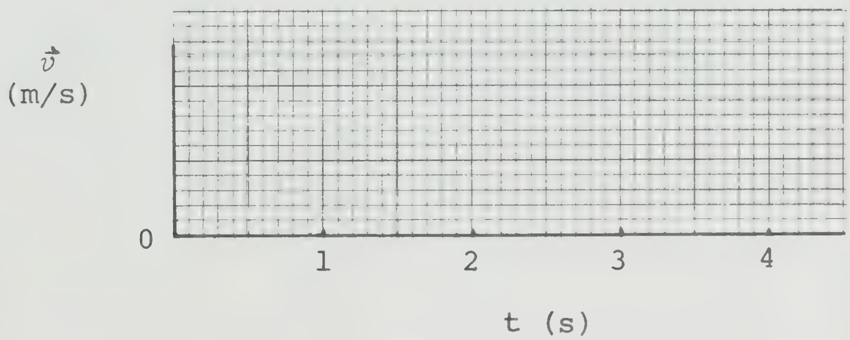
A particle is moving as shown by the position-time graph plotted below.

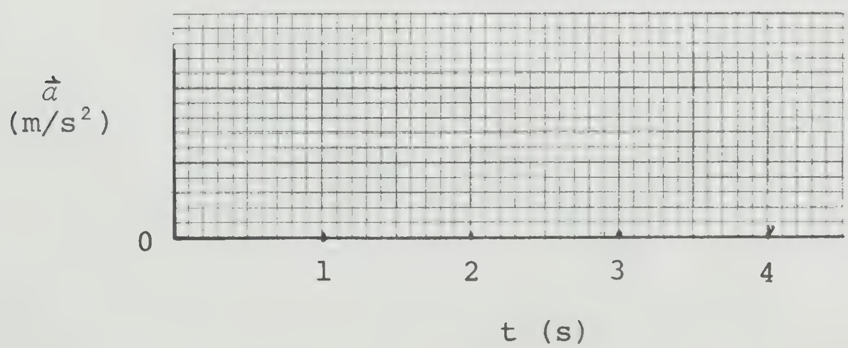


Using the axes and grids provided, plot the following graphs:

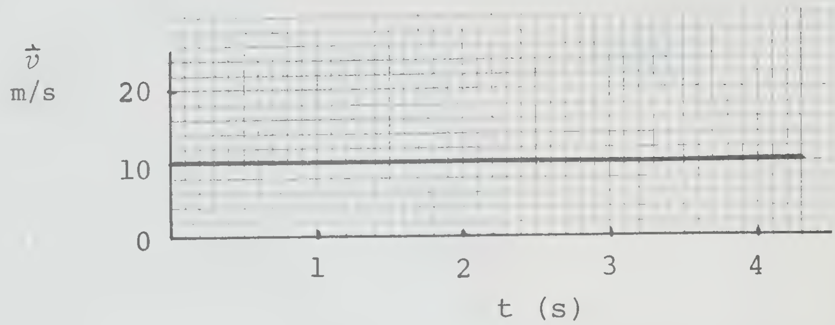
(a) velocity versus time



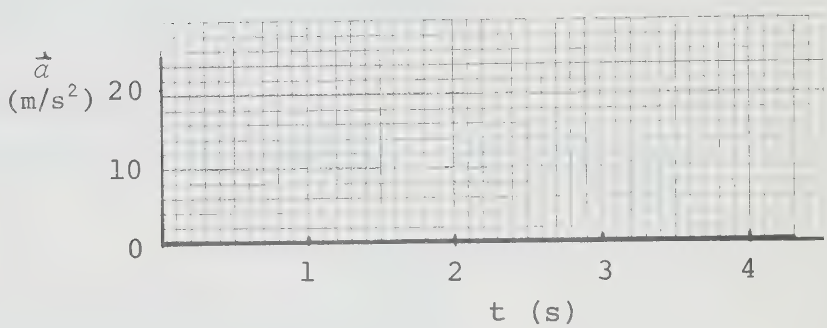
(b) acceleration versus time



Scoring Scheme	Answer
√ shape √ position √	(a)



Scoring Scheme	Answer
√ shape √ position	(b)



6

S17A
I.2.a
S17C
I.3.b

18

A7
A2

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The area under a velocity-time graph for a certain time interval represents the ____________ during the interval.

Scoring Scheme	Answer
√	displacement or change in position

7

S17A
I.2.a
S17C
I.3.b

18

A11
A7

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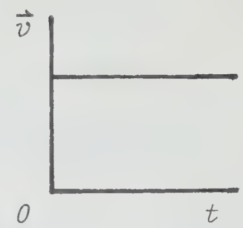
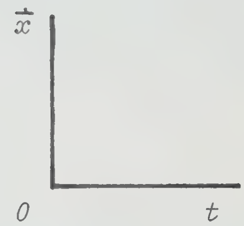
The velocity-time graph for an object travelling in a straight line is shown.

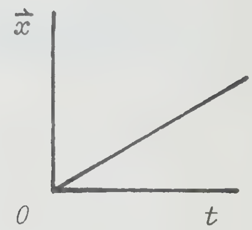


Using the axes provided, sketch the shape of the position-time graph for the object's motion.



Scoring Scheme	Answer
√	graph a straight line
√	positive slope

NOTE: The graph need not start at the origin.



8

S17A
I.2.a
S17C
I.3.b

18

A11
A7

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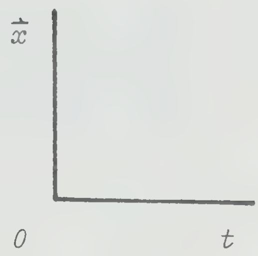
The velocity-time graph for an object travelling in a straight line is shown.

Using the axes provided, sketch the shape of the position-time graph for the object's motion.



Scoring Scheme	Answer
√	correct shape ($d \propto t^2$)
√	slope at origin zero

9

S17A
I.2.a
S17C
I.3.b

18

A11
A7

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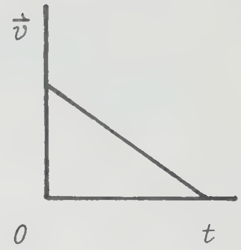
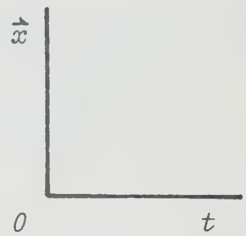
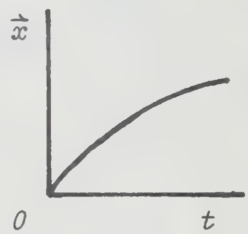
The velocity-time graph for an object travelling in a straight line is shown.



Using the axes provided, sketch the shape of the position-time graph for the object's motion.



Scoring Scheme	Answer
√	correct shape of curve about t axis
√	slope approaching zero with time



10

In the equation $d = v \cdot \Delta t$, what is the meaning of the symbol Δt?

S17A
I.2.a
S17C
I.3.c

19

A2

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Scoring Scheme | Answer

√ $t_2 - t_1$

or $t_n - t_{n-1}$

or an increment in t

or an interval of t

11 Consider the equation $\vec{v}_f = \vec{v}_i + \vec{a}t$.

S17A
I.2.a
S17C
I.3.c

19

A11

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(a) State the meaning of the arrows over the symbols $\vec{v}_f$, $\vec{v}_i$, and $\vec{a}$.

(b) State why there is no arrow over the symbol "t".

(c) State what each symbol represents.

(d) Rearrange the equation to solve for t.

Scoring Scheme | Answer

✓ (a) The arrows indicate that the physical quantities represented by these symbols are vector quantities.

✓ (b) "t" represents a scalar quantity (time).

✓ (c) $\vec{v}_f$ represents the final velocity.

✓ $\vec{v}_i$ represents the initial velocity.

✓ $\vec{a}$ represents the acceleration

✓ t represents the time interval between the initial and final velocities.

✓ (d) $t = \dfrac{\vec{v}_f - \vec{v}_i}{\vec{a}}$

12

A skier accelerates at 5 m/s^2. What is the increase in speed of the skier between the fourth and fifth seconds?

S17A
I.2.a
S17C
I.3.b

19

F1
A8
A3

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Scoring Scheme

Answer

$a = 5$ m/s^2 $t_1 = 4$ s $t_2 = 5$ s

$\Delta t = 5$ s $- 4$ s

✓ $= 1$ s

$\Delta v = a\ \Delta t$

$= (5$ m/s$^2)$ $(1$ s$)$

✓ ✓ $= 5$ m/s

✓ The increase in speed of the skier is 5 m/s.

13 If a skier accelerates down a hill at 5 m/s^2, by how much does the speed change in 1 s?

S17A
I.2.a
S17C
I.3.b

19

F1
A3
A8

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Scoring Scheme — Answer

$a = 5\ m/s^2$ $\Delta t = 1\ s$

$\Delta v = a\Delta t$

$= (5\ m/s^2)\ (1\ s)$

√ √ $= 5\ m/s$

√ The speed changes by 5 m/s every second.

14 The equation $\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$ is used to describe motion.

S17A
I.2.a
S17C
I.3.b

S 19

A11
A8

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(a) Express in words the meaning of each symbol in the equation.

(b) Express in words the meaning of the equation.

Scoring Scheme	Answer
✓ ✓ ✓	(a) $\vec{a}$ represents acceleration $\Delta\vec{v}$ represents change in velocity Δt represents an interval of time
✓ ✓ ✓	(b) Acceleration equals the rate of change of velocity with time.

15 The equation $v_{av} = \frac{d}{t}$ is used to describe motion.

S17A
I.2.a
S17C
I.3.a

S 20

A11
A8

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(a) Express in words the meaning of each symbol in the equation.

(b) Express in words the meaning of the equation.

Scoring Scheme	Answer
√	(a) v_{av} represents average speed
√	d represents distance travelled
√	t represents the time interval
√ √ √	(b) Average speed is equal to the total distance travelled divided by the total time taken.

6

A 2 kg ball falls freely from rest. How far will the ball fall in the first second? (g = 10 m/s^2)

S17A
I.2.a
S17C
I.3.c

21

A8

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Scoring Scheme	Answer
	m = 2 kg
√	$v_i = 0$
	g = 10 m/s^2
√	$d = v_i t + \frac{1}{2} at^2$
√	$= 0 + \frac{1}{2} \times 10 \text{ m/s}^2 \times (1 \text{ s})^2$
√ √	= 5 m
√	The ball will fall 5 m in the first second.

17 For a particular body moving with constant acceleration along a straight line

S17A
I.2.a
S17C
I.3.c

$$\vec{v}_i = +3.0 \text{ m/s}$$

$$\vec{a} = -1.0 \text{ m/s}^2$$

21

$$t = 3.0 \text{ s}$$

All
F1

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(a) Without substituting numerical values for any of the variables, write the equation that is suitable for determining the displacement $\vec{d}$ of the body.

(b) Calculate the displacement of the body using the data provided.

Scoring Scheme	Answer
√	(a) $\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$
√	(b) $\vec{d} = (3.0 \text{ m/s})(3.0 \text{ s}) + \frac{1}{2}(-1.0 \text{ m/s}^2)(3.0 \text{ s})^2$
	$= 9.0 \text{ m} - 4.5 \text{ m}$
√ √	$= 4.5 \text{ m}$
√	The displacement of the body is +4.5 m.

18

S17A
I.2.a
S17C
I.3.c

21

All
F1

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For a particular body moving with constant acceleration along a straight line

$$\vec{v}_i = +8.0 \text{ m/s}$$

$$\vec{a} = +2.0 \text{ m/s}^2$$

$$\vec{d} = +1.0 \text{ m}$$

(a) Without substituting numerical values for any of the variables, write the equation that would be suitable for determining the final velocity $\vec{v}_f$ of the body.

(b) Calculate the final velocity of the body using the data provided.

Scoring Scheme	Answer
✓	(a) $\vec{v}_f = \pm\sqrt{v_i^{\,2} + 2ad}$ <u>or</u> $v_f^{\,2} = v_i^{\,2} + 2ad$
✓	(b) $\vec{v}_f = \pm\sqrt{(8.0 \text{ m/s})^2 + 2(2.0 \text{ m/s}^2)(1.0 \text{ m})}$
	$= \pm\sqrt{64 \text{ m}^2/\text{s}^2 + 4.0 \text{ m}^2/\text{s}^2}$
	$= \pm\sqrt{68 \text{ m}^2/\text{s}^2}$
✓ ✓ ✓	$= \pm\ 8.2 \text{ m/s}$
✓	The final velocity is +8.2 m/s since all the other variables are positive.

19 For a particular body moving with constant acceleration along a straight line

S17A
I.2.a
S17C
I.3.c

21

$$\vec{v}_i = 0$$

$$\vec{a} = +6.0\ \text{m/s}^2$$

$$t = 2.0\ \text{s}$$

A11
F1

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(a) Without substituting numerical values for any of the variables, write the equation that is suitable for determining the displacement $\vec{d}$ of the body.

(b) Calculate the displacement of the body using the data provided.

Scoring Scheme	Answer
✓	(a) $\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$
✓	(b) $\vec{d} = (0)\ (2.0\ \text{s}) + \frac{1}{2}(6.0\ \text{m/s}^2)\ (2.0\ \text{s})^2$
✓ ✓	$= 12\ \text{m}$
✓	The displacement of the body is +12 m.

20 For a particular body moving with constant acceleration along a straight line

S17A
I.2.a
S17C
I.3.c

21

$$\vec{v}_i = +5.0 \text{ m/s}$$

$$\vec{a} = +3.0 \text{ m/s}^2$$

$$t = 2.0 \text{ s}$$

A11
F1

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(a) Without substituting numerical values for any of the variables, write the equation that would be suitable for determining the final velocity $\vec{v}_f$ of the body.

(b) Calculate the final velocity of the body using the data provided.

Scoring Scheme	Answer
✓	(a) $\vec{v}_f = \vec{v}_i + \vec{a}t$
✓	(b) $\vec{v}_f = (5.0 \text{ m/s}) + (3.0 \text{ m/s}^2)(2.0 \text{ s})$
✓ ✓	$= 11 \text{ m/s}$
✓	The final velocity of the body is +11 m/s.

2

S17A
I.2.a
S17C
I.3.c

21

All
F1

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For a particular body moving with constant acceleration along a straight line

$$\vec{v}_i = +8.0 \text{ m/s}$$

$$\vec{a} = -2.0 \text{ m/s}^2$$

$$\vec{d} = +1.0 \text{ m}$$

(a) Without substituting numerical values for any of the variables, write the equation that would be suitable for determining the final velocity $\vec{v}_f$ of the body.

(b) Calculate the final velocity of the body using the data provided.

Scoring Scheme	Answer
√	(a) $\vec{v}_f = \pm\sqrt{v_i^2 + 2ad}$ or $v_f^2 = v_i^2 + 2ad$
√	(b) $\vec{v}_f = \pm\sqrt{(8.0 \text{ m/s})^2 + 2(-2.0 \text{ m/s}^2)(1.0 \text{ m})}$
	$= \pm\sqrt{64 \text{ m}^2/\text{s}^2 - 4.0 \text{ m}^2/\text{s}^2}$
	$= \pm\sqrt{60 \text{ m}^2/\text{s}^2}$
√ √ √	$= \pm 7.7$ m/s
√ √	The final velocity of the body is ±7.7 m/s.

22

S17C
I.3.c

21

F1
A3
A8

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Car A, travelling at 20 m/s, passes a stationary car B. At the instant that A passes B, B starts moving with a uniform acceleration of 2.0 m/s^2. After 15 s, where is car A relative to car B?

Scoring Scheme | Answer

✓ $v_A = 20$ m/s, constant $\qquad (v_B)_i = 0$

$t = 15$ s $\qquad a_B = 2.0$ m/s^2

✓ $d_A = v_A t$

✓ $= 20$ m/s x 15 s

✓ ✓ $= 300$ m

✓ $d_B = (v_B)_i t + \frac{1}{2} a_B t^2$

✓ $= 0 + \frac{1}{2}$ x 2 m/s^2 x (15 s)^2

✓ ✓ $= 225$ m

✓ Position of car A with reference to car B = $d_A - d_B$

✓ $= 300$ m - 225 m

✓ ✓ $= 75$ m

✓ ✓ Car A is 75 m ahead of car B after 15 s.

23 An object is released from rest and accelerates uniformly for 1.0 s at 10 m/s^2. Calculate its

S17A
I.2.a (a) final velocity
S17C
I.3.c (b) average velocity

21 (c) displacement

F1
A8

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Scoring Scheme — Answer

$\vec{v}_i = 0$ $t = 1.0$ s $\vec{a} = 10$ m/s^2

✓ (a) $\vec{v}_f = \vec{v}_i + \vec{a}t$

✓ $= 0 + 10 \text{ m/s}^2 \times 1.0 \text{ s}$

✓ ✓ $= 10$ m/s

✓ The final velocity is 10 m/s in the direction of motion.

✓ (b) $\vec{v}_{av} = \dfrac{\vec{v}_i + \vec{v}_f}{2}$

✓ $= \dfrac{0 + 10 \text{ m/s}}{2}$

✓ ✓ $= 5.0$ m/s

✓ The average velocity is 5.0 m/s in the direction of motion.

✓ (c) $\vec{d} = (\dfrac{\vec{v}_i + \vec{v}_f}{2})\, t$

✓ $= 5.0 \text{ m/s} \times 1.0 \text{ s}$

✓ ✓ $= 5.0$ m

✓ The displacement is 5.0 m in the direction of motion.

24 Steve Podborski starts from rest and accelerates uniformly at 3.0 m/s^2 down a ski slope.

S17A
I.2.a (a) How fast is he moving after 1.0 s?
S17C
I.3.d (b) How fast is he moving after 2.0 s?

21 (c) How far has he moved after 1.0 s?

F1 (d) How far has he moved after 3.0 s?
A8

(e) What is his average speed for the first 2.0 s?

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Scoring Scheme	Answer
√	(a) $v_i = 0$ $a = 3.0\ \text{m/s}^2$ $t = 1.0\ \text{s}$
√	$v_f = v_i + at$
√	$= 0 + (3.0\ \text{m/s}^2)\ (1.0\ \text{s})$
√ √	$= 3.0\ \text{m/s}$
√	He is moving with a speed of 3.0 m/s after 1.0 s.
√	(b) $v_f = (3.0\ \text{m/s}^2)\ (2.0\ \text{s})$
√ √	$= 6.0\ \text{m/s}$
√	He is moving with a speed of 6.0 m/s after 2.0 s.
√	(c) $d = \frac{(v_i + v_f)}{2} t$ or $d = v_i t + \frac{1}{2} at^2$
√	$= \frac{(0 + 3.0\ \text{m/s})}{2} (1.0\ \text{s})$ $= 0 + \frac{1}{2}(3.0\ \text{m/s}^2)(1.0\ \text{s})^2$
√ √	$= 1.5\ \text{m}$ $= 1.5\ \text{m}$
√	He has moved a distance of 1.5 m after 1.0 s.

Scoring Scheme	Answer
✓	(d) $d = v_i t + \frac{1}{2}at^2$
✓	$= 0 + \frac{1}{2}(3.0 \text{ m/s}^2)\ (3.0 \text{ s})^2$
	$= (1.5 \text{ m/s}^2)\ (9.0 \text{ s}^2)$
	$= 13.5 \text{ m}$
✓ ✓	$= 14 \text{ m}$
✓	He has moved a distance of 14 m in 3.0 s.
✓	(e) $v_{av} = \frac{v_i + v_f}{2}$
✓	$= \frac{0 + 6.0 \text{ m/s}}{2}$
✓ ✓	$= 3.0 \text{ m/s}$
✓	His average speed for the first 2.0 s is 3.0 m/s.

25

S17A
I.2.a
S17C
I.3.c

21

F1
A8

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A ball is allowed to drop from rest. What is its velocity after 4.2 s? (g = 10 m/s^2)

Scoring Scheme	Answer
	$\vec{v}_i = 0$
✓	$\vec{g} = 10\ \text{m/s}^2$
	$t = 4.2\ \text{s}$
✓	$\vec{v}_f = \vec{v}_i + \vec{g}t$
✓	$= 0 + (10\ \text{m/s}^2)(4.2\ \text{s})$
✓ ✓	$= 42\ \text{m/s}$
✓	The velocity after 4.2 s is 42 m/s down provided it does not hit the ground.

26 A car travels from Kapuskasing to Timmins using Highway 11 and Highway 655. It travels for 1.0 h on Highway 11 at 90 km/h and for 1.1 h on Highway 655 at 70 km/h.

S17A
I.2.a
S17C
I.3.c

21

F1
A8

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(a) Calculate the distance travelled on Highway 11.

(b) Calculate the distance travelled on Highway 655.

(c) What is the total distance from Kapuskasing to Timmins using these two highways.

(d) Before Highway 655 opened, drivers had to travel 226 km between the two cities. If a driver maintained a constant speed of 90 km/h, how long did the journey take?

(e) What time is saved using the new route?

Scoring Scheme	Answer
✓	(a) $t = 1.0$ h
	$v = 90$ km/h
✓	$d_1 = vt$
✓	$= 90$ km/h x 1.0 h
✓ ✓	$= 90$ km
✓	The car travels 90 km on Highway 11.
✓	(b) $t = 1.1$ h
	$v = 70$ km/h
✓	$d_2 = vt$
✓	$= 70$ km/h x 1.1 h
✓ ✓	$= 77$ km
✓	The car travels 77 km on Highway 655.

Scoring Scheme	Answer
	(c) The total distance travelled is the sum of the two distances.
✓	$d_t = d_1 + d_2$
✓	$= 90 \text{ km} + 77 \text{ km}$
	$= 167 \text{ km}$
✓ ✓	$= 1.7 \times 10^2 \text{ km}$
✓	The total distance from Kapuskasing to Timmins using the two highways is 1.7×10^2 km.
✓	(d) $d_t = 226 \text{ km}$
	$v = 90 \text{ km/h}$
✓	$t = \dfrac{d_t}{v}$
✓	$= \dfrac{226 \text{ km}}{90 \text{ km/h}}$
✓ ✓	$= 2.5 \text{ h}$
✓	The journey from Kapuskasing to Timmins took 2.5 h.
✓	(e) The time saved is the difference between the two times.
	Time by old route = 2.5 h
✓	Time by new route = 1.0 h + 1.1 h = 2.1 h
	Time saved = 2.5 h - 2.1 h
✓ ✓	= 0.4 h
✓	Using the new route saves 0.4 h.

27 A body starts from rest and accelerates uniformly at 3.0 m/s^2 for 4.0 s.

S17A
I.2.a
S17C
I.3.c

(a) Without substituting numerical values for any of the variables, write the equation that would be suitable for determining

21 (i) the velocity at the end of 4.0 s

F1
A8

(ii) the displacement during the 4.0 s

(b) Using the data provided, calculate

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(i) the velocity at the end of 4.0 s

(ii) the displacement during the 4.0 s

Scoring Scheme	Answer
✓	(a) (i) $\vec{v}_f = \vec{v}_i + \vec{a}t$
✓	(ii) $\vec{d} = \vec{v}_i t + \frac{1}{2} \vec{a}t^2$
✓	(b) (i) $\vec{v}_f = 0 + (3.0\ m/s^2)\ (4.0\ s)$
✓ ✓	$= 12\ m/s$
✓	The velocity at the end of 4.0 s is 12 m/s forward.
✓	(ii) $\vec{d} = (0)\ (4.0\ s) + \frac{1}{2}(3.0\ m/s^2)\ (4.0\ s)^2$
✓ ✓	$= 24\ m$
✓	The displacement is 24 m forward.

28

S17A
I.2.a
S17C
I.3.c

21

F1
A8

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A bicycle rider, starting from rest, acquires a velocity of 20 km/h [N] in 10 s.

Calculate the average acceleration of the rider in m/s^2.

Scoring Scheme	Answer
✓	$\vec{v}_i = 0$
	$t = 10$ s
	$\vec{v}_f = 20$ km/h [N]
✓ ✓	$= 20 \text{ km/h [N]} \times 1000 \frac{\text{m}}{\text{km}} \times \frac{1}{3600} \frac{\text{h}}{\text{s}}$
	$= \frac{20}{3.6}$ m/s [N]
✓ ✓ ✓	$= 5.6$ m/s [N]
✓	$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$
✓	$= \frac{(5.6 \text{ m/s [N]}) - 0}{10 \text{ s}}$
✓ ✓ ✓	$= 0.56 \text{ m/s}^2$ [N]
✓	The average acceleration of the rider is 0.56 m/s^2 [N].

29 A body has a velocity of 2.0 m/s [E] and then accelerates at 2.0 m/s^2 [W] for 3.0 s.

S17A
I.2.a
S17C
I.3.c

(a) Without substituting numerical values for any of the variables, write the equation that would be suitable for determining

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(i) the velocity at the end of the 3.0 s interval

F1
A8

(ii) the displacement during the 3.0 s interval

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(b) Using the data provided, calculate

(i) the velocity at the end of the 3.0 s interval

(ii) the displacement during the 3.0 s interval

Scoring Scheme	Answer
✓	(a) (i) $\vec{v}_f = \vec{v}_i + \vec{a}t$
✓	(ii) $\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$
	(b) (i) $\vec{v}_i = 2.0$ m/s [E]
✓	$\vec{a} = 2.0$ m/s^2 [W]
	$t = 3.0$ s
✓	Let [E] be positive.
	Then
	$\vec{v}_i = +2.0$ m/s
✓	$\vec{a} = -2.0$ m/s^2
	$\vec{v}_f = \vec{v}_i + \vec{a}t$
✓	$= 2.0\ \text{m/s} + (-2.0\ \text{m/s}^2)\ 3.0\ \text{s}$
	$= 2.0\ \text{m/s} - 6.0\ \text{m/s}$
✓ ✓ ✓	$= -4.0\ \text{m/s}$
✓ ✓	The velocity at the end of 3.0 s is 4.0 m/s [W].

Scoring Scheme	Answer
	(ii) $\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$
✓	$= (2.0\ \text{m/s})\ (3.0\ \text{s}) + \frac{1}{2}(-2.0\ \text{m/s}^2)\ (3.0\ \text{s})^2$
	$= 6.0\ \text{m} - 9.0\ \text{m}$
✓ ✓ ✓	$= -3.0\ \text{m}$
✓ ✓	The displacement during the 3.0 s interval is 3.0 m [W].

30

S17A
I.2.a
S17C
I.3.c

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F1
A8
A2

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An object accelerates at 2 m/s^2 [W]. How long does it take to change its velocity from 4 m/s [W] to 12 m/s [W]?

Scoring Scheme	Answer
	$\vec{a} = 2\ m/s^2$ [W]
✓	$\vec{v}_i = 4$ m/s [W]
	$\vec{v}_f = 12$ m/s [W]
✓	Let [W] be positive.
	Then
✓	$\vec{a} = 2\ m/s^2$ $\vec{v}_i = 4$ m/s $\vec{v}_f = 12$ m/s
✓	$t = \dfrac{v_f - v_i}{a}$
✓	$= \dfrac{12\ m/s - 4\ m/s}{2\ m/s^2}$
	$= \dfrac{8\ m/s}{2\ m/s^2}$
✓ ✓	$= 4$ s
✓	The time required is 4 s.

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S17A
I.2.a
S17C
I.3.c

21

F1
A8
A3

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An object has a constant acceleration of 4.0 m/s^2 [E]. How long does it take for the velocity to change from 15 m/s [W] to 33 m/s [E]?

Scoring Scheme

Answer

$\vec{a} = 4.0 \text{ m/s}^2$ [E]

✓ $\vec{v}_i = 15$ m/s [W]

$\vec{v}_f = 33$ m/s [E]

✓ Let [E] be positive

Then

$\vec{a} = +4.0 \text{ m/s}^2$

✓ $\vec{v}_i = -15$ m/s

$\vec{v}_f = +33$ m/s

✓ $$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{t}$$

✓ $$t = \frac{v_f - v_i}{a}$$

✓ $$= \frac{33 \text{ m/s} - (-15 \text{ m/s})}{4.0 \text{ m/s}^2}$$

$$= \frac{48 \text{ m/s}}{4.0 \text{ m/s}^2}$$

✓ ✓ $$= 12 \text{ s}$$

✓ The time required is 12 s.

32

A car starts from rest and accelerates uniformly. It travels 80 m in the first 10 s. Calculate its speed at the end of 10 s.

S17A
I.2.a
S17C
I.3.c

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F1
A8
A3

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Scoring Scheme	Answer
✓	$v_i = 0$ $d = 80\text{ m}$ $t = 10\text{ s}$
✓	$d = \left(\frac{v_i + v_f}{2}\right) t$
✓	$v_f = \left(\frac{2d}{t}\right) - v_i$
✓	$= \left(\frac{2 \times 80\text{ m}}{10\text{ s}}\right) - 0$
	$= \frac{160\text{ m}}{10\text{ s}}$
✓ ✓	$= 16\text{ m/s}$
✓	The speed at the end of 10 s is 16 m/s.

33

S17C
I.4.a

S 21

A11
A8

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(a) (i) If a body travels d metres in t seconds, what is the equation for its average speed?

(ii) If a body travels 6 m in 2 s, calculate its average speed.

(b) (i) If a body travels one circumference of a circle of radius R, write an expression which corresponds to the distance it has travelled.

(ii) If the time required for a body to travel once around a circle is the period T, write an expression for the average speed of the body in terms of R and T.

(iii) Calculate the average speed of a body that travels once around a circle of radius 2.00 m in a time of 2.00 s.

Scoring Scheme	Answer
✓	(a) (i) $v_{av} = \frac{d}{t}$
✓	(ii) $d = 6$ m $t = 2$ s
✓	$v_{av} = \frac{6\text{ m}}{2\text{ s}}$
✓ ✓	$= 3$ m/s
✓	The average speed is 3 m/s.
✓	(b) (i) $d = 2\pi R$
✓	(ii) $v_{av} = \frac{2\pi R}{T}$
✓	(iii) $R = 2.00$ m $T = 2.00$ s
✓	$v_{av} = \frac{2\pi\ 2.00\text{ m}}{2.00\text{ s}}$
✓ ✓	$= 6.28$ m/s
✓	The average speed of the body is 6.28 m/s.

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S17A
I.2.a
S17C
I.3.c

S 21

F1
A11

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(a) Express in words the meaning of the equation $\vec{v}_f = \vec{v}_i + \vec{a}t$.

(b) Assuming $\vec{a}$ and $\vec{v}_i$ are both positive and $\vec{v}_i$ and t are kept constant, does $\vec{v}_f$ double if $\vec{a}$ is doubled? Explain your answer.

Scoring Scheme	Answer
✓	(a) For a uniformly accelerated body,
✓	the final velocity
✓	is equal to
✓	the initial velocity
✓	plus
✓	the product of
✓	the acceleration
✓	and the time interval
✓	between the initial and final velocities
✓ ✓	(b) $\vec{v}_f$ increases but doesn't double
✓ ✓	It will only double if $\vec{v}_i = 0$, and $\vec{v}_i$ isn't zero since it is positive.

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S17A
I.2.a
S17C
I.3.c

S 21

F1
A11

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(a) Express in words the meaning of the equation $\vec{d} = \left(\frac{\vec{v}_i + \vec{v}_f}{2}\right)t$.

(b) Assuming $\vec{v}_i$ is equal in magnitude but opposite in direction to $\vec{v}_f$, what is the displacement? Explain your answer.

Scoring Scheme	Answer
✓	(a) For a uniformly accelerated body
✓	the displacement it undergoes
✓	is equal to
✓	the product of
✓	half
✓	the sum of
✓	its initial
✓	and final velocities
✓	and
✓	the time interval
✓	between these velocities
✓	(b) $\vec{d} = 0$
	If $\vec{v}_i = -\vec{v}_f$
✓	Then $\vec{v}_i + -\vec{v}_i = 0$
✓	and $\vec{d} = 0$

MOTION IN A PLANE AND VECTORS

1

S17A
I.2.a
S17C
III.1.d

S 23

A4
A11

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Complete the following chart by indicating for each quantity whether it is a vector or a scalar quantity. Also indicate the preferred SI unit.

Quantity	Vector or Scalar	Preferred SI Unit
speed		
force		
energy		
work		
acceleration		
velocity		
distance		
mass		
displacement		
temperature		
heat energy		

Scoring Scheme

Answer

Scoring	Quantity	Vector or Scalar	Preferred SI Unit
✓ ✓	speed	scalar	m/s
✓ ✓	force	vector	N or $kg \cdot m/s^2$
✓ ✓	energy	scalar	J or $kg \cdot m^2/s^2$
✓ ✓	work	scalar	J or $kg \cdot m^2/s^2$
✓ ✓	acceleration	vector	m/s^2
✓ ✓	velocity	vector	m/s
✓ ✓	distance	scalar	m
✓ ✓	mass	scalar	kg
✓ ✓	displacement	vector	m
✓ ✓	temperature	scalar	°C or K
✓ ✓	heat energy	scalar	J or $kg \cdot m^2/s^2$

2

A plane has an airspeed of 100 km/h. The wind is moving directly south east at 25 km/h.

S17C
I.4.d

If the pilot points the plane directly east, what is the speed of the plane relative to the ground?

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A8

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Scoring Scheme

Answer

Let $\vec{v}(p/g)$ represent the velocity of the plane relative to the ground

$\vec{v}(p/a)$ represent the velocity of the plane relative to the air

$\vec{v}(a/g)$ represent the velocity of the air relative to the ground

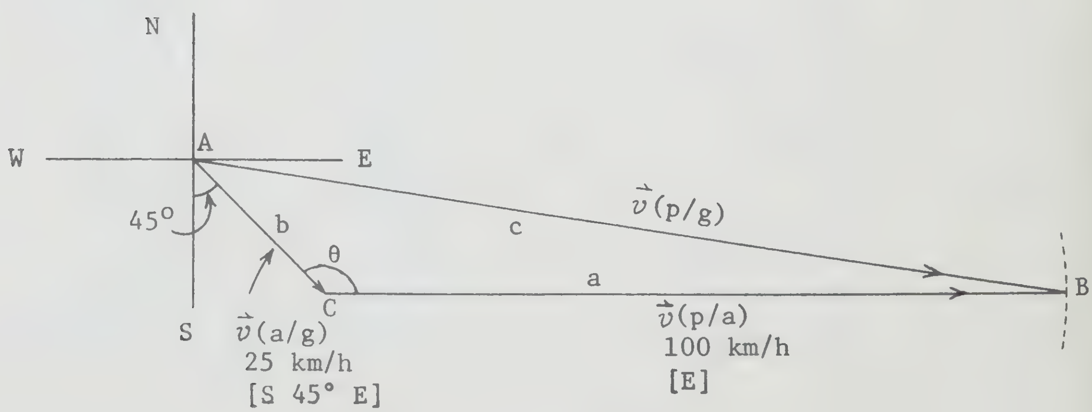
✓ $\vec{v}(p/g) = \vec{v}(p/a) + \vec{v}(a/g)$

$\vec{v}(p/g) = ?$

$\vec{v}(p/a) = 100$ km/h [N 90° E]

✓ $\vec{v}(a/g) = 25$ km/h [S 45° E]

Scale Diagram or Vector Sketch



Scoring Scheme	Answer		
	Vector v(a/g)		
✓	$\vec{v}$(a/g)	or	b labelled
✓	magnitude labelled		25 km/h
✓	direction labelled		[S 45° E]
	Vector v(p/a)		
✓	$\vec{v}$(p/a)	or	a labelled
✓	magnitude labelled		100 km/h
✓	direction labelled		[E]
	Vector v(p/g)		
✓	$\vec{v}$(p/g)	or	c labelled
	Orientation of Vectors		
✓ ✓	correct orientation of v(a/g) and v(p/a) (or b and a) to each other		
✓	correct orientation of v(p/g) (or c) to the other two vectors		

	Solution I: Scale Diagram	
✓	indication of scale	scale: 1 cm represents 10 km/h
✓	appropriateness of scale	
✓	constructed length of v(a/g)	2.5 cm
✓	constructed length of v(p/a)	10 cm
✓	constructed direction of v(a/g)	[S 45° E]
✓	and v(p/a)	[E]
✓	measured length of v(p/g)	12 cm
✓	determination of v(p/g)	12 x 10 km/h = 1.2×10^2 km/h
✓	statement	The speed of the plane with respect to the ground is 1.2×10^2 km/h.

Scoring Scheme	Answer
	Solution II: Cosine Law
✓	$C = 135°$
✓	$c^2 = a^2 + b^2 - 2\ ab \cos C$
✓	$v(p/g)^2 = 100^2 + 25^2 - 2\ (100)\ (25)\ (\cos 135°)$
✓	$= 100^2 + 25^2 - 2\ (100)\ (25)\ (-\frac{\sqrt{2}}{2}$
	$= 100^2 + 25^2 + (100)\ (25)\ (\sqrt{2})$
✓	$= 14\ 160\ km^2/h^2$
✓	$v(p/g) = \sqrt{14\ 160\ km^2/h^2}$
✓ ✓	$= 1.2 \times 10^2\ km/h$
✓	The speed of the plane with respect to the ground is 1.2×10^2 km/h.

3

S17C
I.4.d

24

F1
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A2
A8

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A plane has an airspeed of 100 km/h. The wind is moving directly south east at 25 km/h.

Suppose the pilot wishes to fly directly east. In what direction should the plane head relative to the ground?

Scoring Scheme

Answer

Let $\vec{v}$(p/g) represent the velocity of the plane relative to the ground.

$\vec{v}$(p/a) represent the velocity of the plane relative to the air.

$\vec{v}$(a/g) represent the velocity of the air relative to the ground/

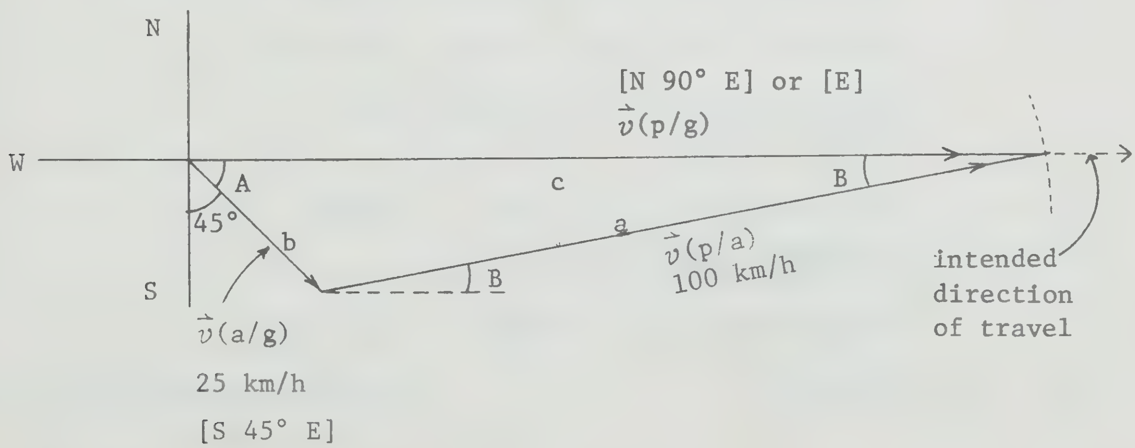
✓ $\vec{v}(p/g) = \vec{v}(p/a) + \vec{v}(a/g)$

$\vec{v}$(p/g) = ? [N 90° E]

$\vec{v}$(p/a) = 100 km/h [N (90 - B)° E]

✓ $\vec{v}$(a/g) = 25 km/h [S 45° E]

Scale Diagram or Vector Sketch



Scoring Scheme	Answer		
	Vector $v(a/g)$		
√	$\vec{v}(a/g)$	or	b labelled
√	magnitude labelled		25 km/h
√	direction labelled		A labelled [S 45° E]
	Vector $v(p/a)$		
√	$\vec{v}(p/a)$	or	a labelled
√	magnitude labelled		100 km/h
	Vector $v(p/g)$		
√	$\vec{v}(p/g)$	or	c labelled
√	direction labelled		[N 90° E] or [E]
	Orientation of Vectors		
√ √	orientation of $v(a/g)$ and $v(p/g)$ (or b and c) to each other		
√	orientation of $v(p/a)$ or a to the other two vectors		

Solution I: Scale Diagram

√	indication of scale	scale: 1 cm represents 10 km/h
√	appropriateness of scale	
√	constructed length of $v(a/g)$	2.5 cm
√	constructed direction of $v(a/g)$	[S 45° E]
√	constructed direction of $v(p/g)$ unknown length	[E]
√	constructed length of $v(p/a)$	10 cm
√	constructed direction of $v(p/a)$	
√	measured direction of $v(p/a)$	[E 10° N]
√	statement	The plane should head [E 10° N].

Scoring Scheme	Answer
	Solution II: Sine Law
✓	$A = 45°$
✓	$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$
✓	$\frac{v(p/a)}{\sin 45°} = \frac{v(a/g)}{\sin B}$
✓	$\sin B = \frac{v(a/g)}{v(p/a)} \sin 45°$
✓	$\frac{25 \text{ km/h}}{100 \text{ km/h}} \quad \frac{1}{\sqrt{2}}$
✓	$= 0.1767$
✓	$\therefore B = 10.18°$
✓	direction of $v(p/a)$ = [E 10° N]
✓	The plane should head [E 10° N].

4

S17C
I.4.d

24

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A plane has an airspeed of 100 km/h. The pilot points the plane directly north. A wind is blowing from the west at 40 km/h.

Using a vector diagram, find the velocity of the plane relative to the ground.

<u>Scoring Scheme</u> <u>Answer</u>

Let $\vec{v}(p/g)$ represent the velocity of the plane relative to the ground.

$\vec{v}(p/a)$ represent the velocity of the plane relative to the air.

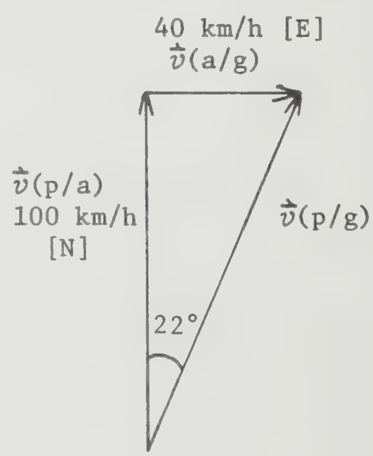
$\vec{v}(a/g)$ represent the velocity of the air relative to the ground.

✓ Then $\vec{v}(p/g) = \vec{v}(p/a) + \vec{v}(a/g)$

$\vec{v}(p/a) = 100$ km/h [N]

✓ $\vec{v}(a/g) = 40$ km/h [E]

$\vec{v}(p/g) = ?$



<u>Vector $v(p/a)$</u>

✓ $\vec{v}(p/a)$ labelled

✓ magnitude labelled 100 km/h

✓ direction labelled [N]

Scoring Scheme	Answer	
	Vector v(a/g)	
√	$\vec{v}$(a/g) labelled	
√	magnitude labelled	40 km/h
√	direction labelled	[E]
	Vector v(p/g)	
√	$\vec{v}$(p/g) labelled	
	Orientation of Vectors	
√ √	orientation of v(a/g) and v(p/a) to each other	
√	orientation of v(p/g) to the other two vectors	
	Solution: Scale Diagram	
√	indication of scale	Scale: 1 cm represents 20 km/h
√	appropriateness of scale	
√	constructed length of v(p/a)	5 cm
√	constructed direction of v(p/a)	[N]
√	constructed length of v(a/g)	2 cm
√	constructed direction of v(a/g)	[E]
√	measured length of v(p/g)	5.4 cm
√	determination of v(p/g)	5.4 x 20 km/h
√		= 1.1 x 10^2 km/h
√	measured direction of v(p/g)	[N 22° E]
√ √	statement	The velocity of the plane with respect to the ground is 1.1 x 10^2 km/h [N 22° E].

5 A trip of 320 km at an average speed of 80 km/h takes a time of ________ h.

S17A
I.2.a
S17C
I.3.a

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F1
A8

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Scoring Scheme	Answer	
√	d = 320 km	v = 80 km/h
√	$t = d/v$	
√	$= \frac{320 \text{ km}}{80 \text{ km/h}}$	
√ √	= 4.0 h	

6

A car travels at an average speed of 60 km/h for 5.0 h. What distance does it cover in this time?

S17A
I.2.a
S17C
I.3.c

S 27

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A8
A3

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Scoring Scheme	Answer
✓	$v_{av} = 60$ km/h
	$t = 5.0$ h
✓	$d = v_{av}\ t$
✓	$= 60$ km/h x 5.0 h
	$= 300$ km
✓ ✓	$= 3.0 \times 10^2$ km
✓	The car travels a distance of 3.0×10^2 km.

7 Determine the component due east of the velocity vector shown.

S17C
I.4.d

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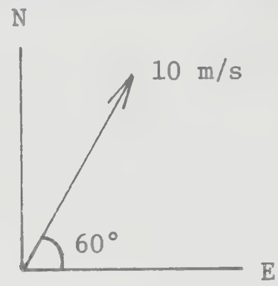

Scoring Scheme	Answer
√	$v_E = v \cos \theta$
√	$= 10$ m/s x cos 60°
√	$= 10$ m/s x 0.500
√ √	$= 5.0$ m/s
√	The component due east is 5.0 m/s.
	or
√	statement of scales of diagram
√	projection on to E axis
√	measurement of projection
√ √	final answer
√	statement

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S17C
I.4.d

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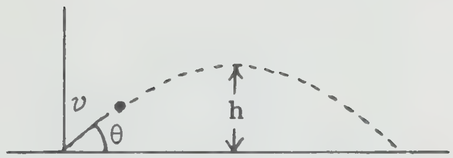
A projectile is fired with a speed v at an angle θ above the horizontal. Show that the maximum height reached will be $h = \frac{v^2 \sin^2 \theta}{2\,g}$, where g is the gravitational acceleration.

Scoring Scheme	Answer
✓	Suitable sketch 
	Consider the vertical components of the motion.
✓	Let up be positive
✓ ✓	$v_i = v \sin \theta$
✓	$v_f = 0$, at maximum height
	$d = h$, the maximum height
✓	$a = -g$, opposite to the direction of v_i
✓	$v_f^2 - v_i^2 = 2\,ad$
✓	$d = \frac{v_f^2 - v_i^2}{2\,a}$
✓	$h = \frac{0 - (v \sin \theta)^2}{2\,(-g)}$
✓	$= \frac{-v^2 \sin^2 \theta}{-2\,g}$
✓	$= \frac{v^2 \sin^2 \theta}{2\,g}$

9 A cannon fires a shell with a muzzle velocity $\vec{v}_o$ of 1000 m/s at an angle 30° above the horizontal.

S17C
I.4.d Calculate the horizontal component of its velocity.

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F1
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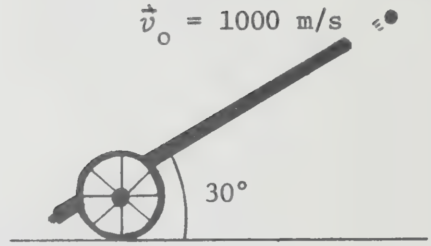

Scoring Scheme	Answer
✓	suitable sketch
✓	$\vec{v}_{horizontal} = \vec{v}_o \cos\theta$
✓	$= 1000$ m/s x cos 30°
✓	$= 1000$ m/s x 0.866
✓ ✓	$= 8.7 \times 10^2$ m/s
✓	The horizontal component of the velocity is 8.7×10^2 m/s.
	<u>or</u>
✓	suitable sketch
✓	statement of scale of diagram
✓	projection on to horizontal axis
✓	measurement of projection
✓ ✓	final answer
✓	statement

10 A ball is thrown horizontally from the roof of a tall building with a velocity of 20 m/s [E]. Ignore air resistance. Find:

S17C
I.4.e

(a) the vertical distance the ball falls in the first second

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(b) the position of the ball with respect to the release point at the end of the first second.

F1
A8
A3

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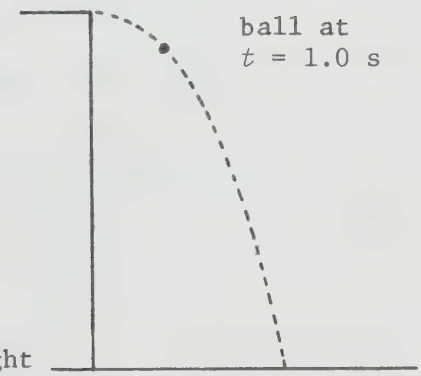
Scoring Scheme	Answer
✓	Suitable sketch
✓	$\vec{v}_i = 20$ m/s [E]
	(a) Consider the vertical component of the motion:
	$\vec{v}_i = 0$
✓	$\vec{a} = 10 \text{ m/s}^2$
	$t = 1.0$ s
✓	$\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$
✓	$= 0 + \frac{1}{2}(10 \text{ m/s}^2)(1.0 \text{ s})^2$
✓ ✓	$= 5.0$ m below its initial height
✓	The object falls a distance of 5.0 m in the first second.
✓	(b) Both horizontal and vertical components must be considered here.
✓	$\vec{d}_{\text{vertical}} = 5.0$ m below the initial height
✓	$\vec{d}_{\text{horizontal}} = \vec{v}_{\text{horizontal}} \times t$
✓	$= 20$ m/s [E] x 1.0 s
✓ ✓ ✓	$= 20$ m [E]
✓ ✓	The position is 5.0 m below and 20 m [E] of its initial position.



11 A ball is thrown horizontally from the roof of a tall building with a velocity of 20 m/s [E]. (g = 10 m/s^2) Ignore air resistance. Find:

S17C
I.4.e

(a) the vertical component of the object's velocity after 4.0 s of fall

29

(b) the resultant velocity after 4.0 s of fall

F1
A8
A3

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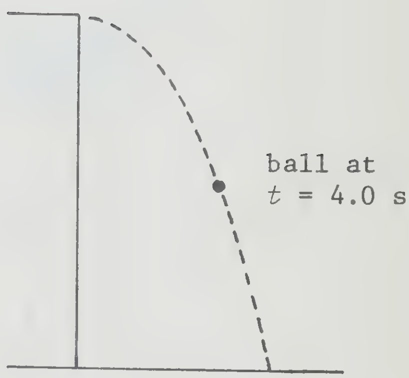
Scoring Scheme	Answer
✓	(a) appropriate sketch
	Consider the vertical motion
✓	Let downward be positive.
✓	$\vec{v}_i = 0$
✓	$\vec{a} = 10\ \text{m/s}^2$
	$t = 4.0$ s
✓	$\vec{v}_f = \vec{v}_i + \vec{a}t$
✓	$= 0 + (10\ \text{m/s}^2)(4.0\ \text{s})$
✓ ✓	$= 40$ m/s
✓ ✓	The vertical component of the object's velocity after 4.0 s of fall is 40 m/s downward

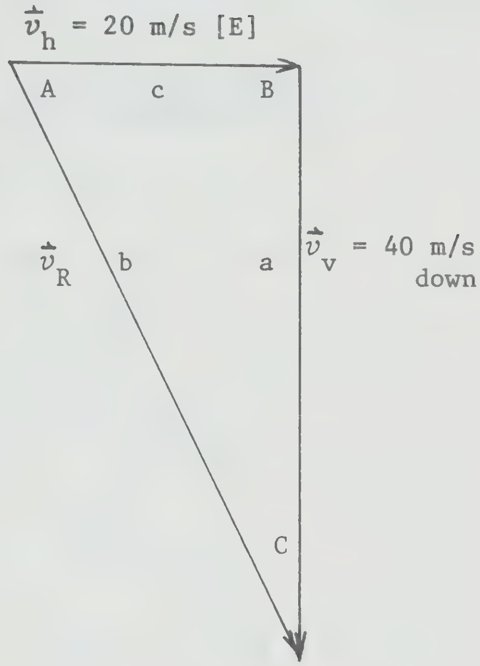


(b) $\vec{v}_R = \vec{v}_h + \vec{v}_v$

$\vec{v}_h$ = 20 m/s [E]

$\vec{v}_v$ = 40 m/s downward

Scoring Scheme	Answer	
	Sketch or Vector Diagram	
	Horizontal Velocity	
√	$\vec{v}_h$ or c labelled	
√	magnitude labelled	
√	direction labelled	
	Vertical Velocity	
√	$\vec{v}_v$ or a labelled	
√	magnitude labelled	
√	direction labelled	
	Resultant Velocity	
√	$\vec{v}_R$ labelled	



Scoring Scheme	Answer	
	Orientation of Vectors	
√ √	orientation of v_h and v_b (or c and a) to each other	
√	orientation of v_R to the other two vectors	
	Solution 1: Scale Drawing	
√	indication of scale	Scale: Let 1 cm represent 5 m/s.
√	appropriateness of scale	
√	constructed length of v_h	4 cm
√	constructed direction of v_h	[E]
√	constructed length of v_v	8 cm
√	constructed direction of v_v	downward
√	measured length of v_R	9 cm
√	determination of v_R	9 x 5 m/s = 45 m/s

Scoring Scheme	Answer	
✓	measured direction of v_R	[E] 64° below horizontal
✓ ✓	statement	The resultant velocity after 4.0 s is 45 m/s [E] 64° below the horizontal.

Solution II: Pythagorean Theorem

✓ $v_R^2 = v_h^2 + v_v^2$

✓ $= (20 \text{ m/s})^2 + (40 \text{ m/s})^2$

$= 400 \text{ m}^2/\text{s}^2 + 1600 \text{ m}^2/\text{s}^2$

$= 2000 \text{ m}^2/\text{s}^2$

✓ $v_R = \sqrt{2000 \text{ m}^2/\text{s}^2}$

✓ ✓ $= 45 \text{ m/s}$

✓ $\text{Tan } A = \frac{a}{c}$

✓ $= \frac{40}{20}$

✓ $= 2.0$

✓ $A = 64°$

✓ ✓ ∴ the resultant velocity after 4.0 s is 45 m/s [E] 64° below horizontal.

12

S17C
I.4.e

An aircraft is flying horizontally with a speed of 900 km/h. It is 80 m above level ground when it releases a 150 kg bomb. (g = 10 m/s^2) Ignore air resistance.

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(a) After the bomb is released, how many seconds does it take to reach the ground?

F1
A8

(b) How far in front of a target must the bomb be released in order to hit the target?

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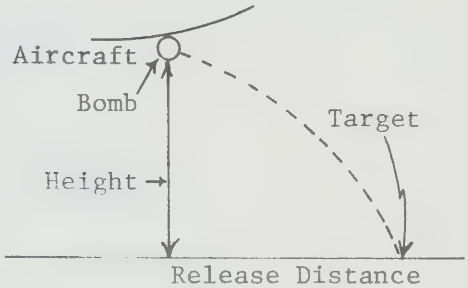
Scoring Scheme	Answer
✓	Suitable sketch
✓	The bomb has the same velocity as the aircraft when released. The horizontal and vertical components of the motion are independent.



(a) For the Vertical Motion

✓	Let down be positive
✓	$\vec{d}$ = 80 m $\vec{v}_1 = 0$ $\vec{g} = \vec{a}$ = 10 m/s^2
✓	The vertical motion has constant acceleration if friction is ignored.
✓	$\vec{d} = \vec{v}_1 t + \frac{1}{2}\vec{a}t^2$
✓	$t = \sqrt{\dfrac{d - v_1 t}{\frac{1}{2} a}}$
✓	$= \sqrt{\dfrac{80 \text{ m} - 0}{\frac{1}{2}(10 \text{ m/s}^2)}}$
✓ ✓	= 4.0 s
✓	The bomb remains in the air for 4.0 s.

Scoring Scheme	Answer
	(b) For the Horizontal Motion
✓	The horizontal motion has constant velocity.
✓	$\vec{v} = 900 \text{ km/h}$
	$t = 4.0 \text{ s}$
✓	$= 4.0 \text{ s} \times \frac{1 \text{ h}}{3600 \text{ s}}$
	$= \frac{1}{900} \text{ h}$
✓	$\vec{d} = \vec{v}t$
✓	$= 900 \text{ km/h} \times \frac{1}{900} \text{ h}$
✓ ✓	$= 1.0 \text{ km}$
✓	The bomb must be released 1.0 km in front of the target.

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S17C
I.4.e

S 29
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F1
A8
A3

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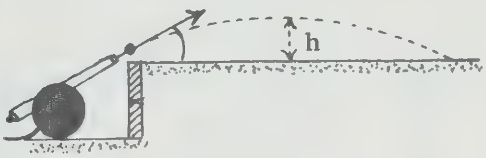
A cannon situated on level ground fires a shell with a muzzle velocity of 100 m/s at an angle of 30° above the horizontal. Ignore air resistance and the height of the muzzle of the cannon. (g = 10 m/s^2)

Calculate:

(a) the time required for the shell to reach its maximum height

(b) the maximum height attained.

Scoring Scheme	Answer
✓	Suitable sketch



Let $\vec{v}_o$ represent the muzzle velocity.

✓ Then $\vec{v}_o$ = 100 m/s at 30° above the horizontal.

✓ Let up be positive.

(a) Consider the Vertical Component

The vertical component of the motion has constant acceleration.

$\vec{a}$ = 10 m/s^2 down

✓ $= -10$ m/s^2

$\vec{v}_i$ = vertical component of $\vec{v}_o$

✓ $= \vec{v}_o \times \sin 30°$

✓ = 100 m/s x 0.500

✓ ✓ = 50 m/s

✓ $\vec{v}_f = 0$ (since the shell is stopped)

✓ $\vec{v}_f = \vec{v}_i + \vec{a}t$

Scoring Scheme	Answer
✓	$t = v_f - v_i/a$
✓	$= \dfrac{0 - 50\text{ m/s}}{-10\text{ m/s}^2}$
✓ ✓	$= 5.0\text{ s}$
✓	The time required to reach the maximum height is 5.0 s.
	(b) Consider the Vertical Component
✓	The vertical component of $\vec{v}_o$ determines the maximum height.
✓	$\vec{v}_i = 50\text{ m/s}$ $\vec{v}_f = 0$ $t = 5.0\text{ s}$
✓	$\bar{h} = \left(\dfrac{\vec{v}_i + \vec{v}_f}{2}\right)t$
✓	$= \left(\dfrac{50\text{ m/s} + 0}{2}\right) 5.0\text{ s}$
✓ ✓	$= 125\text{ m}$
✓	The maximum height attained is 1.3×10^2 m (2 significant figures).

14

S17C
I.4.e

S 29
21

F1
A8
A3

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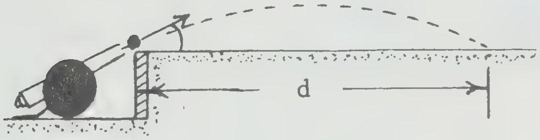
A cannon situated on level ground fires a shell with a muzzle velocity of 100 m/s at an angle of 30° above the horizontal. The shell hits the ground 10 s later. Ignore air resistance and the height of the muzzle of the cannon. (g = 10 m/s^2)

Calculate the distance the shell travels horizontally before striking the ground.

Scoring Scheme	Answer
√	Suitable sketch 
	Let $\vec{v}_o$ represent the muzzle velocity.
√	Then $\vec{v}_o$ = 100 m/s at 30° above the horizontal.
√	The horizontal component of the motion has constant velocity.
√	The horizontal component of $\vec{v}_o$ determines the range.
	v = horizontal component of $\vec{v}_o$
√	$= \vec{v}_o \cos 30°$
	t = 10 s
√	$\vec{d} = \vec{v}t$
√	$= \vec{v}_o \cos 30° \times 10$ s
√	= 100 m/s x 0.8660 x 10 s
√ √	= 866 m
√	The range is 8.7 x 10^2 m (2 significant figures).

15

S17C
I.4.f

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F1
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A8

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A car travelled around a circular path of radius 14 m at a constant speed. The centripetal acceleration was 7.0 m/s².

(a) At what speed did it travel?

(b) How long did it take for one complete lap around the track?

Scoring Scheme — Answer

✓ $r = 14$ m $\quad$ v is constant $\quad$ $a = 7.0\ \text{m/s}^2$

✓ (a) $a = \frac{v^2}{r}$

$v^2 = ar$

✓ $v = \pm\sqrt{ar}$

✓ $= \pm\sqrt{7.0\ \text{m/s}^2 \times 14\ \text{m}}$

$= \pm\sqrt{98\ \text{m}^2/\text{s}^2}$

✓ ✓ $= \pm\ 9.9$ m/s

✓ The car travelled at 9.9 m/s.

✓ (b) $a = \frac{4\pi^2 r}{T^2}$

$T^2 = \frac{4\pi^2 r}{a}$

✓ $T = \sqrt{\frac{4\pi^2 r}{a}}$

✓ $= \sqrt{\frac{4\pi^2\ 14\ \text{m}}{7.0\ \text{m/s}^2}}$

$= \sqrt{8\pi^2\ s^2}$

✓ ✓ $= 8.9$ s

✓ The car took 8.9 s for one complete lap.

D Y N A M I C S

FORCE AND NEWTON'S LAWS

1 A boy applies a force of 90 N along the handle of a lawn roller as represented in the diagram. The mass of the lawn roller is 40 kg. (g = 10 N/kg)

S17C
III.1.d

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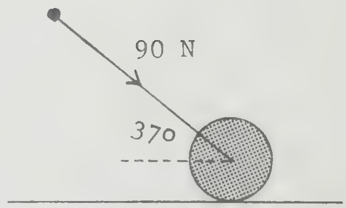

Determine:

F1
A3
A7

(a) the component of the 90 N force that pushes the lawn roller forward

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(b) the component of the 90 N force that pushes the lawn roller toward the ground

(c) the magnitude of the gravitational force on the roller

(d) the total downward force on the roller

(e) the net vertical force on the roller

Scoring Scheme	Answer	
	F = 90 N along handle	θ = angle between horizontal and handle
√	m = 40 kg	= 37°
	g = 10 N/kg	
√	(a) $F_{\text{forward}} = F \cos \theta$	
√	= 90 N x cos 37°	
√	= 90 N x 0.799	
√ √	= 72 N	
√	The component of the force forward is 72 N.	

Scoring Scheme	Answer
✓	(b) $F_{down} = F \sin \theta$
✓	$= 90\ \text{N} \times \sin 37°$
✓	$= 90\ \text{N} \times 0.602$
✓ ✓	$= 54\ \text{N}$
✓	The component of the force downward is 54 N.
✓	(c) $F_g = mg$
✓	$= 40\ \text{kg} \times 10\ \text{N/kg}$
✓ ✓	$= 400\ \text{N}$
✓	The magnitude of the force of gravity on the roller is 400 N.
✓	(d) $F(\text{total, downward}) = F_{down} + F_g$
✓	$= 54\ \text{N} + 400\ \text{N}$
✓ ✓	$= 454\ \text{N}$
✓	The total downward force on the roller is 454 N.
✓	(e) $\vec{a}_{vertical} = 0$
✓	$\vec{F}_{vertical} = m\vec{a}_{vertical}$
✓	$= 0$
	<u>or</u>
✓	Since there is no vertical motion (vertical acceleration is zero)
✓	the vertical forces must be balanced.
✓	The net vertical force on the roller is 0.

2

S17C
III.1.d

31

F1
A7
A2

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A force of 60 N [N] acts on an object. Another force of 80 N [N 75° E] acts on the object at the same time.

(a) Find the resultant of the two forces.

(b) What force is needed to balance the two forces?

Scoring Scheme

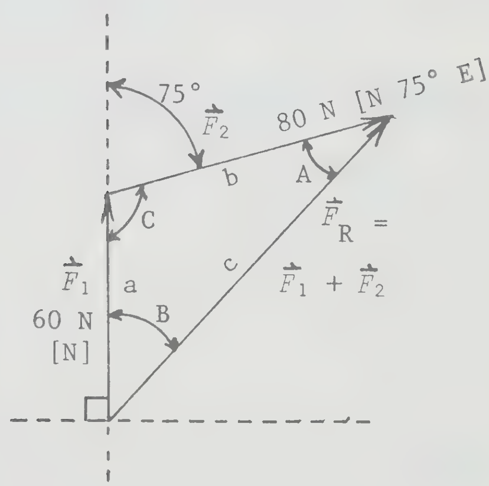
Answer

✓ (a) $\vec{F}_1$ = 60 N [N]

$\vec{F}_2$ = 80 N [N 75° E]

✓ $\vec{F}_R = \vec{F}_1 + \vec{F}_2$

Sketch or Scale Diagram



Vector F_1

✓	$\vec{F}_1$ or	a labelled
✓	magnitude labelled	60 N
✓	direction labelled	[N]

Scoring Scheme	Answer		
	Vector F_2		
√	$\vec{F}_2$	or	b labelled
√	magnitude labelled		80 N
√	direction labelled		[N 75° E]
	Resultant Vector		
√	$\vec{F}_R$	or	c labelled
	Orientation of Vectors		
√ √	orientation of F_1 and F_2 to each other		
√	orientation of F_R to the other two vectors		
	Solution I: Scale Drawing		
√	indication of scale	scale:	let 1 cm represent 20 N
√	appropriateness of scale		
√	constructed length of F_1		3 cm
√	constructed direction of F_1		[N]
√	constructed length of F_2		4 cm
√	constructed direction of F_2		[N 75° E]
√	measured length of F_R		5.6 cm
√	determination of F_R		5.6 x 20 N
√			= 1.1×10^2 N
√	measured direction of F_R		[N 44° E]
√ √	statement		The resultant force is 1.1×10^2 N [N 44° E].

Scoring Scheme	Answer
	Solution II: Trigonometric
	Cosine Law
√	$C = 105°$
√	$\cos C = \cos 105° = -\cos 75°$
√	$c^2 = a^2 + b^2 - 2ab \cos C$
√	$F_R{}^2 = 60^2 + 80^2 - 2(60)(80)(-\cos 75°)$
√	$= 3600 + 6400 + 9600\ (0.2588)$
√	$= 12\ 484\ N^2$
	$F_R = \sqrt{12\ 484\ N^2}$
√ √	$= 1.1 \times 10^2\ N$
	Sine Law
√	$\frac{\sin B}{b} = \frac{\sin C}{c}$
	$\sin B = \frac{b}{c} \sin C$
√	$= \frac{80}{1.1 \times 10^2} \sin 105°$
√	$= \frac{80}{1.1 \times 10^2} (0.9659)$
√	$= 0.6899$
√	$B = 44°$
√	The direction of the resultant force is [N 44° E].
√ √	The resultant force is 1.1×10^2 [N 44° E].
	NOTE: Multiply the trigonometric solution by 0.75 to equate the ticks to the scale drawing solution.
√ √ √	(b) The force needed to balance the two forces F_1 and F_2 is 1.1×10^2 N [S 44° W].

3 A force of 9 N [S] and a force of 12 N [W] are applied to an object.

S17C
III.1.d Find the resultant of the two forces.

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F1
A7
A2

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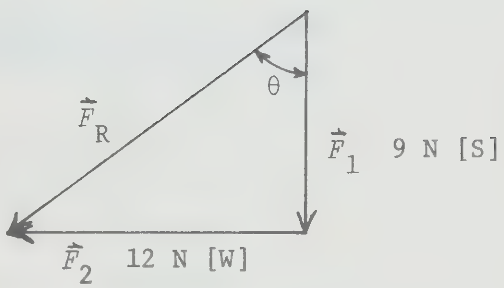
Scoring Scheme — Answer

$\vec{F}_1 = 9$ N [S]

✓ $\vec{F}_2 = 12$ N [W]

$\vec{F}_{Net} = \vec{F}_1 + \vec{F}_2$

Sketch or Scale Diagram



Vector F_1

$\vec{F}_1$ labelled

✓ magnitude labelled

✓ direction labelled

Vector F_2

✓ $\vec{F}_2$ labelled

✓ magnitude labelled

✓ direction labelled

Vector F_R

✓ $\vec{F}_R$ labelled

Vector Orientation

✓ ✓ orientation of F_1 and F_2 to each other

✓ orientation of F_R to the other two

Scoring Scheme	Answer	
	Solution I: Scale Drawing	
✓	indication of scale	Scale: Let 1 cm represent 3 N
✓	appropriateness of scale	
✓	constructed length of F_1	3 cm
✓	constructed direction of F_1	[S]
✓	constructed length of F_2	4 cm
✓	constructed direction of F_2	[W]
✓	measured length of F_R	5 cm
✓	determination of F_R	5 x 3 N = 15 N
✓	measured direction of F_R	53°
✓	direction of F_R	S 53° W
✓ ✓	statement	The resultant of the two forces is 15 N [S 53° W].
	Solution II: Pythagorean Theorem	
✓	$F_R{}^2 = F_1{}^2 + F_2{}^2$	
✓	$= 81\ N^2 + 144\ s^2$	
✓	$= 225\ N^2$	
	$F_R = \sqrt{225\ N^2}$	
✓ ✓	$= 15\ N$	
✓	Let θ be the angle between the resultant and $\vec{F}_1$.	
✓	$\tan\theta = \frac{12\ N}{9\ N}$	
✓	$= 1.33$	
✓	$\theta = 53°$	
✓	The direction of F_R is S 53° W.	
✓ ✓	The resultant of the two forces is 15 N [S 53° W].	

4 A parachutist, whose mass is 80 kg, is falling at a constant vertical velocity of 8.0 m/s.

S17A
I.2.c
S17C
III.1.d

What is the net (unbalanced) force on the parachutist? Explain your answer.

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A3
A8

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Scoring Scheme	Answer
√	$\vec{a} = 0$
√	$\vec{F}_{Net} = m\vec{a}$
√	$= 0$
√	The unbalanced force is zero.
	or
√√√√	Newton's First Law - the unbalanced force is zero because the body is falling at constant velocity.

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S17A
I.2.b
S17C
III.1.d

32
21

F1
A8

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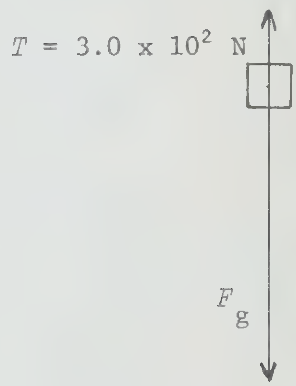
A girl of mass 40 kg plans to elope from home by sliding down a 6.0 m long rope improvised from panty hose. The rope will withstand a maximum load of 3.0×10^2 N. (g = 10 N/kg)

Calculate the minimum possible acceleration that the girl can allow herself without breaking the rope.

Scoring Scheme	Answer
✓ ✓	Acceptable free body diagram.
✓	Let downward be positive.
✓	$m = 40$ kg $T_{max} = -3.0 \times 10^2$ N
✓	$d = 6.0$ m $g = 10$ N/kg
✓	$F_g = mg$
✓	$= (40 \text{ kg})(10 \text{ N/kg})$
✓	$= 4.0 \times 10^2$ N
✓	$\vec{F} = \vec{T}_{max} + \vec{F}_g$
✓	$= -3.0 \times 10^2 \text{ N} + (4.0 \times 10^2 \text{ N})$
✓	$= 1.0 \times 10^2$ N
✓	The minimum unbalanced force is 1.0×10^2 N downward.
✓	$a = \dfrac{F}{m}$
✓	$= \dfrac{1.0 \times 10^2 \text{ N}}{40 \text{ kg}}$
✓ ✓	$= 2.5 \text{ m/s}^2$
✓	The minimum acceleration is 2.5 m/s^2 downward.



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A girl of mass 40 kg plans to elope from home by sliding down a 6.0 m long rope improvised from panty hose. The rope will withstand a maximum load of 3.0×10^2 N. (g = 10 N/kg)

If she arrives at ground level at a speed greater than 9.0 m/s she will sprain her ankle. Calculate the <u>maximum</u> possible acceleration the girl can allow herself without injuring her ankle.

S17A
I.2.b
S17C
III.1.d

32
21

F1
A8

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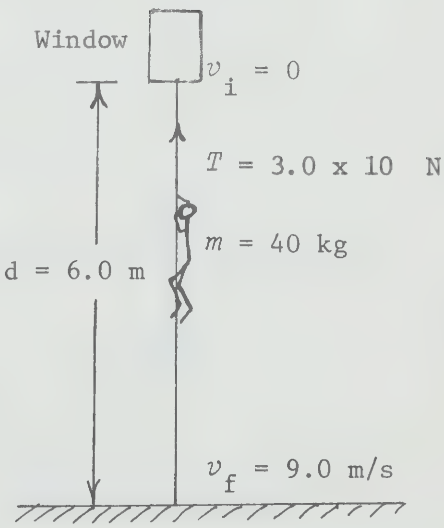
Scoring Scheme	Answer
✓	Suitable sketch.
	Let downward be positive.
✓	$m = 40$ kg $T_{max} = 3.0 \times 10^2$ N
✓	$v_i = 0$
✓	$v_f = 9.0$ m/s
✓	$d = 6.0$ m
✓	$v_f^2 = v_i^2 + 2ad$
✓	$a = \dfrac{v_f^2 - v_i^2}{2d}$
✓	$= \dfrac{(9.0 \text{ m/s})^2 - 0}{2\ (6.0 \text{ m})}$
✓ ✓	$= 6.8 \text{ m/s}^2$
✓	The maximum allowable acceleration is 6.8 m/s^2 downward.



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S17A
I.2.c
S17C
III.2.a

S 32

F1
A8
A2

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A crate weighing 1000 N is dragged across a level floor. A force of 200 N is needed to drag the crate at constant speed.

Find the coefficient of kinetic friction between the crate and the floor.

Scoring Scheme	Answer
	Let N be the normal force exerted by the floor on the crate.
√	$N = \lvert F_g \rvert$
√	$= 1000\ \mathrm{N}$
√	The force to overcome friction = 200 N forward.
√	∴ the force of kinetic friction = 200 N backward.
√	$\mu_k = \dfrac{\lvert F_f \rvert}{\lvert N \rvert}$
√	$= \dfrac{200\ \mathrm{N}}{1000\ \mathrm{N}}$
√	$= 0.200$
√	The coefficient of kinetic friction between the crate and the floor is 0.200.

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S17A
I.2.c
S17C
III.1.d

S 32

F1
A8
A2

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A crate weighing 4200 N is resting on the shop floor. The coefficient of static friction between the crate and the floor is 0.200. A man can exert a maximum horizontal force of 850 N.

Can the man move the crate? Show all calculations.

Scoring Scheme	Answer
✓	$\vec{F}_g = 4200$ N down $\quad \vec{F}_a = 850$ N forward
	$\mu_s = 0.200$
✓	$N = \lvert F_g \rvert$
✓	$\lvert F_f \rvert = \mu_s \lvert N \rvert$
✓	$= 0.200 \times 4200$ N
✓ ✓	$= 840$ N
✓ ✓	The man must exert a force slightly greater than 840 N to overcome static friction.
✓	Since $\vec{F}_a = 850$ N
✓	and 850 N > 840 N
✓	∴ the man can move the crate

9

S17A
I.2.c
S17C
III.2.a

S 32

F1
A8
A2

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A wooden crate weighing 360 N is dragged across a level concrete floor. A force of 60 N is needed to drag the crate at constant speed.

Calculate the coefficient of kinetic friction for wood on concrete.

Scoring Scheme	Answer
√	$N = \lvert F_g \rvert$
√	$= 360\ \text{N}$
√	$F_f = 60\ \text{N}$
√	$\mu_k = \dfrac{\lvert F_f \rvert}{\lvert N \rvert}$
√	$= \dfrac{60\ \text{N}}{360\ \text{N}}$
√	$= 0.17$
√	The coefficient of kinetic friction for wood on concrete is 0.17.

10	A block of wood weighs 8.5 N. The coefficient of static friction between it and the vertical wall against which it is pressed is 0.30.
S17A I.2.c S17C III.2.a S 32 F1 A8 A2 ** ** -	Determine if a force on the block of 3.0 N perpendicular to the wall is enough to prevent the block from sliding downward. Show all calculations.

Scoring Scheme	Answer
✓	$\vec{F}_g = 8.5$ N down
	$\mu_s = 0.30$
✓	$\vec{F}_f = 8.5$ up to prevent slipping
✓	The horizontal force is equal to the normal force between the wall and the block.
✓	$\lvert N \rvert = \dfrac{\lvert F_f \rvert}{\mu_s}$
✓	$= \dfrac{8.5 \text{ N}}{0.30}$
✓ ✓	$= 28$ N
✓	A horizontal force of 28 N is needed to prevent the block from sliding downward.
✓	Therefore a horizontal force of 3.0 N is <u>not</u> sufficient.

11	A leather covered box weighing 60 N rests on a horizontal pine table. The coefficient of static friction between leather and pine is 0.60.	
S17A I.2.c S17C III.2.a	What is the <u>minimum</u> force required to start the box moving?	
S 32		
F1 A8 A2		
** ** ***		

<u>Scoring Scheme</u>	<u>Answer</u>
✓	$\vec{F}_g = 60$ N down
	$\mu_s = 0.60$
✓	$\lvert N\rvert = 60$ N (same as magnitude of $\vec{F}_g$)
✓	$\mu_s = \dfrac{\lvert F_s\rvert}{\lvert N\rvert}$
✓	$\lvert F_s\rvert = \mu_s\lvert N\rvert$
✓	$= (0.60)\ (60\text{ N})$
✓ ✓	$= 36$ N
✓	The minimum force required is 36 N forward.

12

S17A
I.2.c
S17C
III.2.a

S 32

F1
A8
A2

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**

A book has a weight of 45 N. The coefficient of static friction between the book and plaster is 0.45. Calculate the force required to press the book against a plaster wall to prevent it from slipping.

Scoring Scheme	Answer
✓	$\mu_s = 0.45$
	$\vec{F}_g = 45$ N down
✓ ✓	$\therefore\ \vec{F}_f = 45$ N up
✓	$\mu_s = \dfrac{\lvert F_f \rvert}{\lvert N \rvert}$
✓	where N is the force pushing the two surfaces together
✓	$\lvert N \rvert = \dfrac{\lvert F_f \rvert}{\mu_s}$
✓	$= \dfrac{45\ \text{N}}{0.45}$
✓ ✓	$= 100$ N
✓	The book must be pressed against the wall with a force of 100 N.

13

S17A
I.2.c
S17C
III.2.a

S 32

F1
A8
A2

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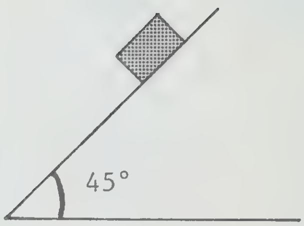
A metal block just begins to slide down an incline when the angle between it and the horizontal is 45°.

Calculate the coefficient of static friction.

Scoring Scheme	Answer
✓	Suitable sketch.
✓	Let θ be the angle of inclination when the block begins to slide.
✓	$\theta = 45°$
✓	$\tan\theta = \mu_s$
✓	$\tan 45° = 1$
✓	$\therefore \ \mu_s = 1$
✓	The coefficient of static friction is 1.



14 The motion of an object is described by the velocity-time graph given below.

S17A
I.2.c
S17C
III.1.d

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17

A11
A7

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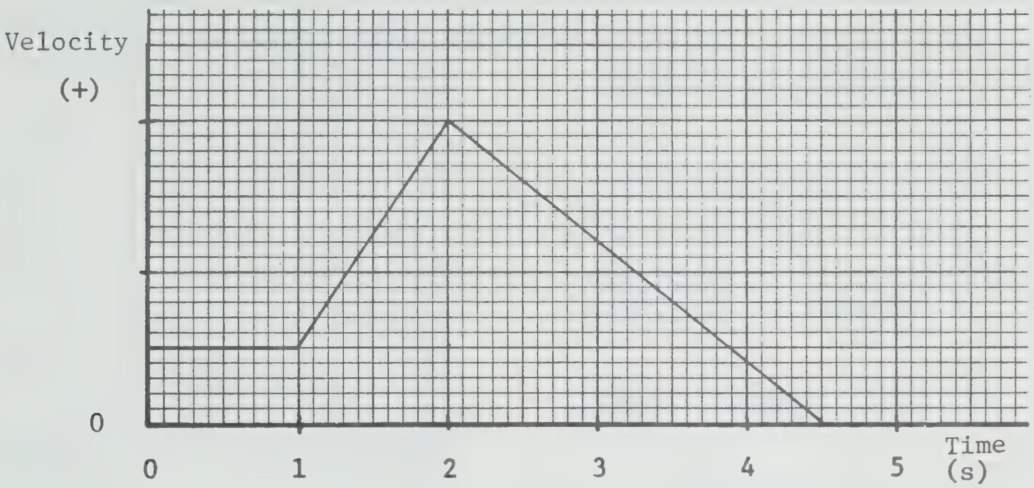
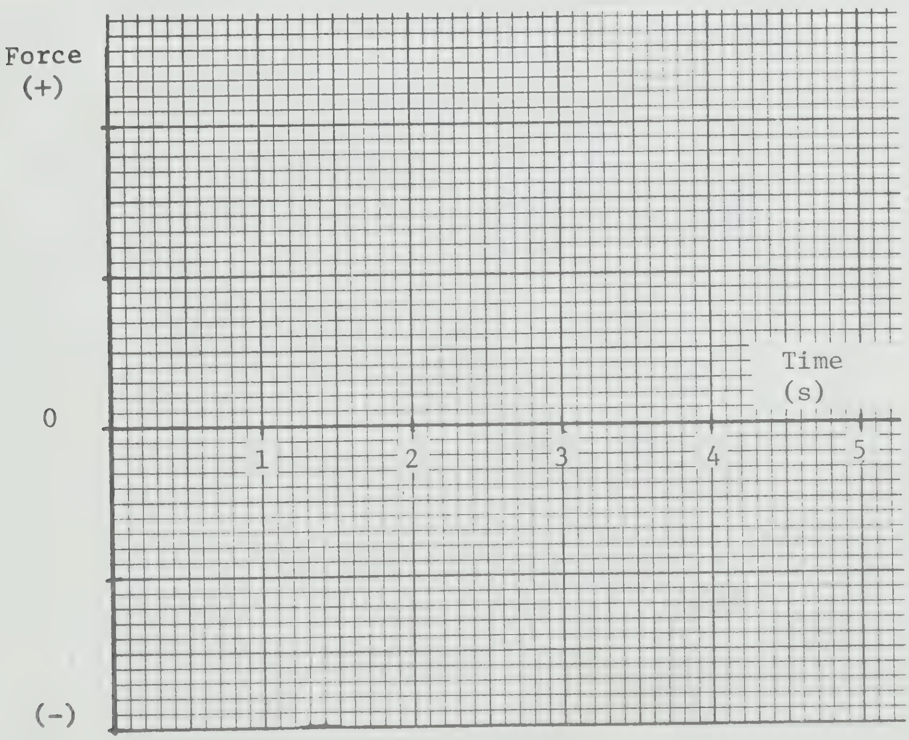


Using the axes and grid provided below, draw a graph of unbalanced force versus time for the motion of the object.



Scoring Scheme

√ correct shape of segment from t = 0 to t = 1 s

√ correct position of segment from t = 0 to t = 1 s

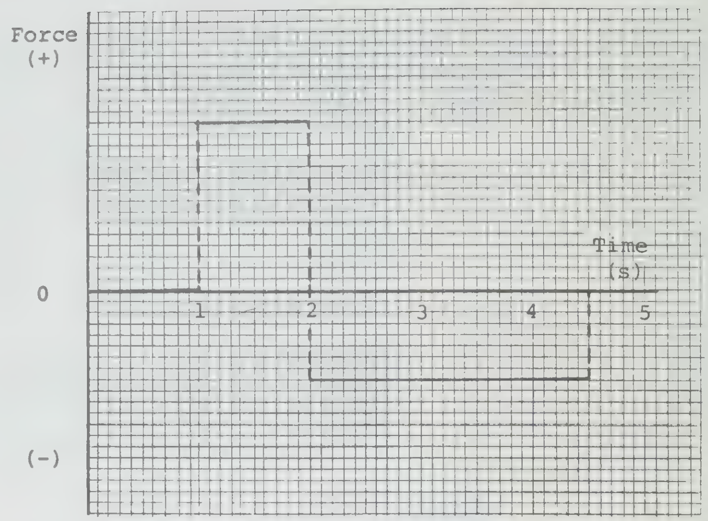
√ correct shape of segment from t = 1 s to t = 2 s

√ appropriate position of segment from t = 1 s to t = 2 s

√ correct shape of segment from t = 2 s to t = 4.5 s

√√ correct position of segment from t = 2 s to t = 4.5 s compared to position from t = 1 s to t = 2 s

Answer



15

A brick is at rest on a smooth, level surface. A force of 20 N gives the brick an acceleration of 32 m/s^2.

S17A
I.2.c
S17C
III.1.d

Determine the mass of the brick.

35

F1
A8
A3

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Scoring Scheme	Answer
✓	$a = 32\ m/s^2$
	$F = 20\ N$
✓	$F = ma$
✓	$m = \frac{F}{a}$
✓	$= \frac{20\ N}{32\ m/s^2}$
✓ ✓	$= 0.63\ kg$
✓	The mass of the brick is 0.63 kg.

16

S17C
III.2.a

35

F1
A8
A3

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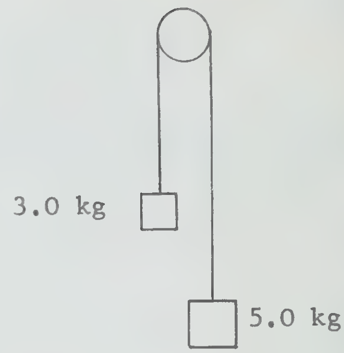
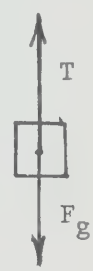
A 3.0 kg mass is attached to a 5.0 kg mass by a light thread which passes over a frictionless peg. When the masses are released from rest, what is the magnitude of the tension in the thread? (g = 10 N/kg)



Scoring Scheme	Answer
✓	g = 10 N/kg m_L = 3.0 kg m_R = 5.0 kg
	Let a be the acceleration of the system in m/s^2.
	Let T be the magnitude of the tension in the thread in N.
✓	The magnitude of the acceleration of the 3.0 kg mass is the same as the magnitude of the acceleration of the 5.0 kg mass.
	<u>Consider the 3.0 kg mass</u>
✓ ✓	Free body diagram
✓	$F_g = mg$
	= 3.0 kg x 10 N/kg down
✓	= 30 N down
✓	T is larger than F_g
✓	Net force $F = T - F_g$
✓	$F = (T - 30)$N
✓	m = 3.0 kg $a = a$ m/s^2
✓	$F = ma$
✓	$T - 30 = 3.0\ a$ (1)



Scoring Scheme	Answer
	Consider the 5.0 kg Mass
✓ ✓	Free body diagram
	$F_g = mg$
	$= 5.0$ kg x 10 N/kg down
✓	$= 50$ N down
✓	F_g is larger than T
✓	$\therefore$ Net force $F = F_g - T$
✓	$F = (50 - T)$N
✓	$m = 5.0$ kg $a = a$ m/s^2
✓	$F = ma$
✓	$50 - T = 5.0\ a$ (2)
	Solving the two equations for T
✓	substitute $a = \frac{50 - T}{5.0}$ for a in (1).
✓	$T - 30 = 3.0\ \frac{(50 - T)}{5.0}$
	$= \frac{150 - 3.0\ T}{5.0}$
✓	$5.0\ T - 150 = 150 - 3.0\ T$
	$8.0\ T = 300$
	$T = \frac{300}{8.0}$
✓ ✓	$= 38$ N
✓	The magnitude of the tension in the thread is 38 N.

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S17C
III.2.a

35

F1
A8
A3

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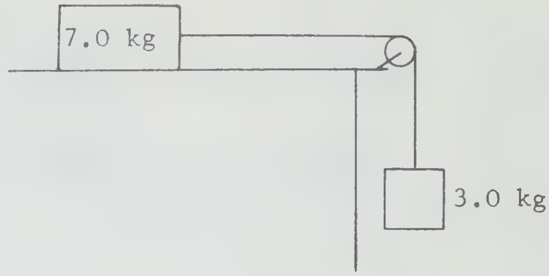
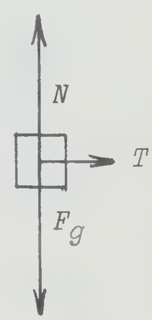
A 7.0 kg mass rests on a frictionless table and is attached to a 3.0 kg mass by a light thread which passes over a frictionless pulley.
(g = 10 N/kg)



Calculate the magnitude of the tension in the thread after the masses are released.

Scoring Scheme	Answer
√	g = 10 N/kg m_1 = 7.0 kg m_2 = 3.0 kg
√	Let clockwise be positive.
	Let T be the magnitude of the tension in the thread in N.
	Let a be the acceleration of the system in m/s^2.
√	The magnitude of the acceleration of the 3.0 kg mass is the same as the magnitude of the acceleration of the 7.0 kg mass.
	Consider the 7.0 kg mass
√ √ √	Free body diagram
	m = 7.0 kg
	a = a m/s^2
	F = T N
√	$F = ma$
√	$T = 7.0\ a$ (1)
	Consider the 3.0 kg mass
√ √	Free body diagram
	m = 3.0 kg
	a = a m/s^2



Scoring Scheme	Answer
✓	$F = (F_g - T)\text{N}$
✓	$F_g = mg$
	$= 3.0 \text{ kg} \times 10 \text{ N/kg}$
✓	$= 30 \text{ N}$
✓	$F = ma$
✓	$30 - T = 3.0\, a$ (2)

Solve the equations for T

✓	substitute $a = \frac{T}{7.0}$ for a in equation (2)
✓	$30 - T = 3.0 \left(\frac{T}{7.0}\right)$
	$210 - 7.0\,T = 3.0\,T$
	$10\,T = 210$
✓ ✓	$T = 21 \text{ N}$
✓	The tension in the thread is 21 N.

18

S17C
III.2.a

35

F1
A8
A3

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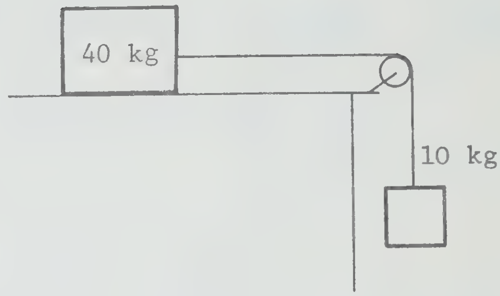
A 40 kg block lies on a frictionless table and is connected to a 10 kg block by a rope passing over a frictionless pulley. (g = 10 N/kg) (Remember that acceleration is a vector quantity.)



(a) What is the acceleration of the 10 kg block?

(b) What is the acceleration of the 40 kg block?

Scoring Scheme

Answer

✓ m_1 = 40 kg m_2 = 10 kg g = 10 N/kg

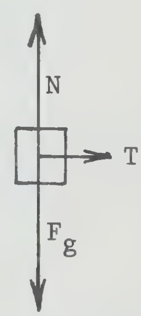
Let T be the magnitude of the tension in the rope in N.

Let a be the acceleration of the system in m/s^2.

✓ The magnitude of the acceleration of the 10 kg mass is the same as the magnitude of the acceleration of the 40 kg mass.

(a) Consider the 40 kg mass

✓ ✓ ✓ Free body diagram



m = 40 kg

✓ $a = a$ m/s^2

$F = T$N

✓ $F = ma$

✓ $T = 40\ a$ (1)

Consider the 10 kg mass

✓ ✓ Free body diagram

m = 10 kg

✓ $a = a$ m/s^2

Scoring Scheme	Answer
✓	$F = (F_g - T)\text{N}$
	$F = ma$
✓	$(F_g - T) = 10\ a$
✓	$F_g = mg$
	$= 10\ \text{kg} \times 10\ \text{N/kg}$
✓ ✓	$= 100\ \text{N}$
✓	$(100 - T) = 10\ a$ (2)
	Solve the equations for a
✓	substitute $T = 40\ a$ for T in (2).
✓	$100 - 40\ a = 10\ a$
	$50\ a = 100$
✓ ✓	$a = 2.0\ \text{m/s}^2$
✓ ✓	The acceleration of the 10 kg mass is $2.0\ \text{m/s}^2$ down.
✓ ✓	(b) The acceleration of the 40 kg mass is $2.0\ \text{m/s}^2$ to the right.

19

S17A
I.2.c
S17C
III.1.d

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19

F1
A8
A3

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A 12 kg object initially at rest is acted upon by two forces at the same time. One force is 8.0 N [E]. The other force is 12 N [W].

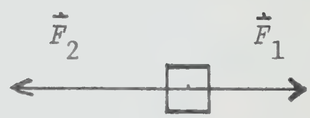
(a) Find the net force acting on the object.

(b) Calculate the acceleration of the object.

(c) Determine the velocity of the object after 26 s.

Scoring Scheme | Answer

✓ ✓ Free body diagram.



✓ $\vec{F}_1 = 8.0$ N [E] $\quad \vec{F}_2 = 12$ N [W]

$\vec{v}_i = 0 \quad t = 26$ s

$m = 12$ kg

✓ Let [W] be positive.

Then

✓ $\vec{F}_1 = -8.0$ N $\quad \vec{F}_2 = +12$ N

✓ (a) $\vec{F}_{net} = \vec{F}_1 + \vec{F}_2$

✓ $= -8.0 \text{ N} + 12 \text{ N}$

✓ ✓ $= 4.0$ N

✓ The net force acting on the object is 4.0 N [W].

✓ (b) $\vec{a} = \frac{\vec{F}}{m}$

✓ $= \frac{4.0 \text{ N [W]}}{12 \text{ kg}}$

✓ ✓ ✓ $= 0.33 \text{ m/s}^2$ [W]

✓ The acceleration of the object is 0.33 m/s^2 [W].

Scoring Scheme	Answer
✓	(c) $\vec{v}_f = \vec{v}_i + \vec{a}t$
✓	$= 0 + (0.33\ m/s^2\ [W])\ (26\ s)$
✓ ✓	$= 8.7\ m/s\ [W]$
✓ ✓	The velocity of the object after 26 s is 8.7 m/s [W].

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S17A
I.2.c
S17C
III.1.d

35
19

F1
A8
A3

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A 2.0 kg brick is in motion on a smooth, level surface. For how long must a 6.0 N force act to increase the speed of the brick from 10 m/s to 20 m/s?

Scoring Scheme	Answer	
✓	$F_{net} = 6.0$ N $m = 2.0$ kg	$v_i = 10$ m/s $v_f = 20$ m/s
✓	$a = \frac{F}{m}$	
✓	$= \frac{6.0 \text{ N}}{2.0 \text{ kg}}$	
✓ ✓	$= 3.0 \text{ m/s}^2$	
✓	$a = \frac{v_f - v_i}{t}$	
✓	$t = \frac{v_f - v_i}{a}$	
✓	$= \frac{20 \text{ m/s} - 10 \text{ m/s}}{3.0 \text{ m/s}^2}$	
	$= \frac{10 \text{ m/s}}{3.0 \text{ m/s}^2}$	
✓ ✓	$= 3.3$ s	
✓	The force must act for 3.3 s.	

21

S17A
I.2.c
S17C
III.1.d

35
21

F1
A8
A3

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A 90 kg jogger accelerates uniformly from rest to 10 m/s in 5.0 s.

(a) Calculate the acceleration of the jogger.

(b) Calculate the unbalanced force needed to produce this acceleration.

Scoring Scheme	Answer
	(a) $v_i = 0$
✓	$v_f = 10$ m/s
	$t = 5.0$ s
✓	$a = \frac{v_f - v_i}{t}$
✓	$= \frac{10 \text{ m/s} - 0}{5 \text{ s}}$
✓ ✓	$= 2.0 \text{ m/s}^2$
✓	The acceleration of the jogger is 2.0 m/s^2.
	(b) $m = 90$ kg
✓	$a = 2.0 \text{ m/s}^2$
✓	$F = ma$
✓	$= 90 \text{ kg} \times 2.0 \text{ m/s}^2$
✓	$= 180 \text{ kg}\cdot\text{m/s}^2$
	$= 180$ N
✓ ✓	$= 1.8 \times 10^2$ N
✓	The unbalanced force acting on the jogger is 1.8×10^2 N.

22 A 50 kg skier starts from rest and moves down a hill. The skier reaches a final speed of 12 m/s in 3.0 s.

S17A
I.2.c (a) What is the skier's acceleration?
S17C
III.1.d (b) What net (unbalanced) force acts on the skier?

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21

F1
A8
A3

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Scoring Scheme	Answer
	(a) Let downhill be positive.
	$\vec{v}_i = 0$
✓	$\vec{v}_f = 12\ \text{m/s}$
	$t = 3.0\ \text{s}$
✓	$\vec{a} = \dfrac{\vec{v}_f - \vec{v}_i}{t}$
✓	$= \dfrac{12\ \text{m/s} - 0}{3.0\ \text{s}}$
✓ ✓	$= +4.0\ \text{m/s}^2$
✓	The skier's acceleration is $4.0\ \text{m/s}^2$ downhill.
✓	(b) $m = 50\ \text{kg}$
	$a = +4.0\ \text{m/s}^2$
✓	$F = ma$
✓	$= 50\ \text{kg} \times 4.0\ \text{m/s}^2$
✓	$= 200\ \text{kg}\cdot\text{m/s}^2$
	$= 200\ \text{N}$
✓ ✓	$= 2.0 \times 10^2\ \text{N}$
✓	The net force on the skier is 2.0×10^2 N downhill.

23 Two forces act at the same time on an object. One force is 18 N [W]. The other is 34 N [E].

S17A
I.2.c
S17C
III.1.d

If the acceleration produced is 8.0 m/s^2 [E], determine the mass of the object.

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31

F1
A8
A7

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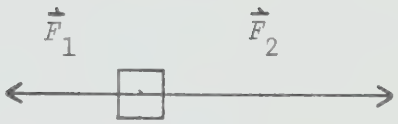
Scoring Scheme	Answer
✓ ✓	Free body diagram.
✓	$\vec{F}_1 = 18$ N [W]
	$\vec{F}_2 = 34$ N [E]
	$\vec{a} = 8$ m/s^2 [E]
✓	Let [E] be positive
	Then
	$\vec{a} = 8$ m/s^2
✓	$\vec{F}_1 = -18$ N
	$\vec{F}_2 = 34$ N
✓	$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2$
✓	$= -18$ N $+ 34$ N
✓	$= +16$ N
✓	$m = \dfrac{F_{net}}{a}$
✓	$= \dfrac{16 \text{ N}}{8.0 \text{ m/s}^2}$
✓ ✓	$= 2.0$ kg
✓	The mass of the object is 2.0 kg.



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S17C
III.1.d

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28

F1
A3

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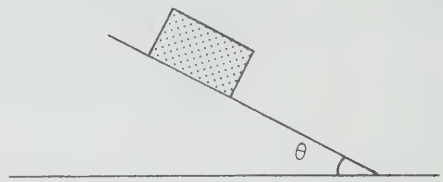
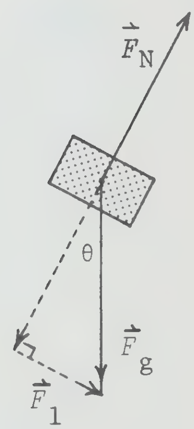
A block slides down an inclined frictionless plane, as shown in the diagram.



Derive the equation to show the magnitude of its acceleration in terms of the acceleration due to gravity g and θ.

Scoring Scheme	Answer
✓ ✓	diagram labelling $\vec{F}_g$ and $\vec{F}_N$
✓ ✓	resolution of $\vec{F}_g$ into components perpendicular and parallel to the ramp
✓	identifying and labelling θ
✓	$\vec{F}_g = m\vec{g}$
✓	$F_1 = F_g \sin\theta$
✓	$= mg \sin\theta$
✓	$F = ma$
✓	$ma = mg \cdot \sin\theta$
✓	$a = g \sin\theta$ is the magnitude of the acceleration along the ramp
✓	The equation is $a = g \sin\theta$.



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S17C
III.1.d

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28

F1
A3
A8

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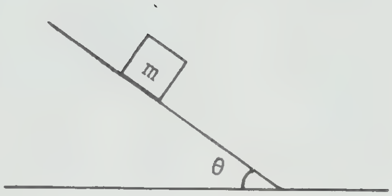
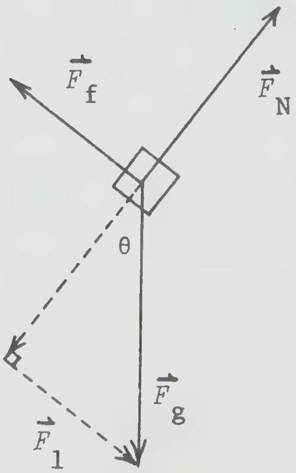
The diagram shows an object of mass m at rest on an inclined plane. The angle the inclined plane makes with the horizontal is θ. A force of friction of magnitude 0.5 times the force of gravity acts on the object and just prevents the mass from sliding.



Determine the value of θ in degrees.

Scoring Scheme	Answer
✓ ✓ ✓	diagram labelling $\vec{F}_g$, $\vec{F}_N$ and $\vec{F}_f$
✓ ✓	resolution of $\vec{F}_g$ into components
✓	identifying and labelling θ
✓	$F_1 = F_g \sin\theta$
✓	$= mg \sin\theta$
✓	$F_f = 0.5\ mg$
	If the mass does not slide, the forces parallel to the ramp must be balanced or
✓	$F_1 = F_f$
✓ ✓	$mg \sin\theta = 0.5\ mg$
✓	$\sin\theta = 0.5$
✓	$\theta = 30°$
✓	The angle the incline makes with the horizontal is 30°.



26 A force of gravity of 20 N downward acts on a book at rest on a rough level table. A horizontal force of 12 N is needed to start the book moving across the table.

S17A
I.2.c
S17C
III.2.a

(a) Calculate the coefficient of static friction.

S 35
31

(b) If an additional downward force of 60 N is applied to the book, calculate the total horizontal force needed to start the book moving.

F1
A8
A3

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Scoring Scheme	Answer
	Let N be the normal force exerted by the table against the surface of the book.
✓	$N = \lvert F_g \rvert$
✓	$= 20$ N
	The force to overcome friction = 12 N forward
✓	The force of friction F_f = 12 N backward.
✓	(a) $\mu_s = \dfrac{\lvert F_f \rvert}{\lvert N \rvert}$
✓	$= \dfrac{12 \text{ N}}{20 \text{ N}}$
✓	$= 0.60$
✓	The coefficient of static friction is 0.60.
✓	(b) $N = 60 \text{ N} + 20 \text{ N}$
✓	$= 80$ N
	$\mu_s = 0.60$
✓	$F_f = \mu_s \text{ N}$
✓	$= (0.60)\ (80 \text{ N})$
✓ ✓	$= 48$ N
✓	The total force needed is 48 N forward.

CENTRIPETAL FORCE AND GRAVITATION

1 A ferris wheel of radius 8.0 m revolves once every 20 s. Determine the centripetal force on a 100 kg man seated in one of the cars.

S17C
III.2.c

38

F1
A8
A3

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Scoring Scheme	Answer
✓	$r = 8.0$ m $T = 20$ s $m = 100$ kg
	$a = \frac{v^2}{r}$
	$v = \frac{2\pi r}{T}$
✓	$\therefore a = \frac{4\pi^2 r}{T^2}$
✓	$F = ma$
✓	$= \frac{m4\pi^2 r}{T^2}$
✓	$= \frac{(100 \text{ kg})\ 4\pi^2\ (8.0 \text{ m})}{(20 \text{ s})^2}$
	$= 8.0\ \pi^2$ N
✓ ✓	$= 79$ N
✓	The centripetal force is 79 N toward the centre of the wheel.

2

The sweep second hand on a watch is 1.5 cm long. Calculate the magnitude of the average acceleration of the tip of the second hand from 9:15:15 until 9:15:45.

S17C
III.2.c

38

F1
A8
A3

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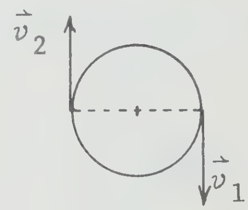
Scoring Scheme | Answer

✓ $r = 1.5$ cm $\quad t_1 = 9{:}15{:}15 \quad t_2 = 9{:}15{:}45$

$T = t_2 - t_1$

✓ $= 60$ s



✓ $v = \dfrac{2\pi r}{T}$

✓ $= \dfrac{2\pi\ (1.5\ \text{cm})}{60\ \text{s}}$

✓ $= 0.05\ \pi$ cm/s

✓ $a_{av} = \dfrac{|\vec{v}_2 - \vec{v}_1|}{\Delta t}$

✓ $= \dfrac{2v}{\Delta t}$

✓ $= \dfrac{2\ (0.05\ \pi\ \text{cm/s})}{30\ \text{s}}$

$= (3.33 \times 10^{-3})\ \pi\ \text{cm/s}^2$

✓ ✓ $= 1.1 \times 10^{-2}\ \text{cm/s}^2$

✓ The average acceleration of the tip of the second hand is $1.1 \times 10^{-2}\ \text{cm/s}^2$.

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S17C
III.2.c

38

F1
A8
A3

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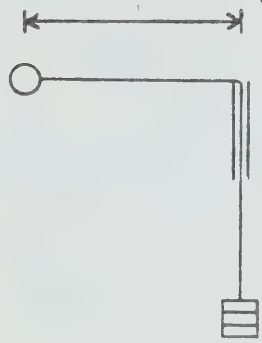
A rubber stopper is attached to a string. The string passes through a frictionless tube and is attached to washers having a total mass of 0.32 kg. Assume that the stopper is whirled horizontally in a circle of radius 0.50 m as shown in the diagram. The stopper makes 10 revolutions in 5.0 s.



Find the magnitude and direction of the centripetal acceleration of the stopper.

Scoring Scheme	Answer
√	$r = 0.50$ m $\quad m_w = 0.32$ kg, total mass of washers
	10 rotations in 5.0 s
	T = time for one rotation = period
√	$= \frac{5.0 \text{ s}}{10}$
√ √	$= 0.50$ s
	$v = \frac{2\pi r}{T}$
√	$a_c = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$
√	$= \frac{4\pi^2 (0.50 \text{ m})}{(0.50 \text{ s})^2}$
√ √	$= 79 \text{ m/s}^2$
√ √	The centripetal acceleration is 79 m/s^2 towards the centre of the circle.

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S17C
III.2.c

38

F1
A8
A3

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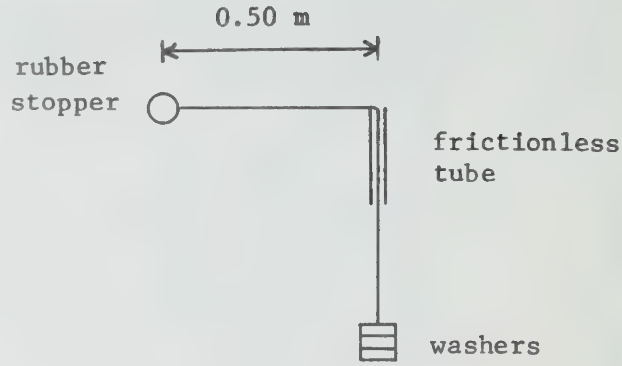
A rubber stopper is attached to a string. The string passes through a frictionless tube and is attached to washers having a total mass of 0.32 kg. Assume that the stopper is whirled horizontally in a circle of radius 0.50 m as shown in the diagram. The washers remain at rest in the vertical when the centripetal acceleration of the stopper is 79 m/s^2. (g = 10 N/kg)



Find the mass of the rubber stopper.

Scoring Scheme | Answer

r = 0.50 m $\quad$ m_w = 0.32 kg

✓ a_c = 79 m/s^2 $\quad$ g = 10 N/kg

✓ The gravitational force on the washers provides the centripetal force on the stopper.

✓ $F_c = F_g$

✓ $m_s a_c = m_w g$

✓ m_s 79 m/s^2 = 0.32 kg·10 N/kg

✓ $m_s = \dfrac{3.2\ \text{N}}{79\ \text{m/s}^2}$

✓ ✓ $= 4.1 \times 10^{-2}$ kg

✓ The mass of the stopper is 4.1×10^{-2} kg.

5 Kepler's Third Law states that

S17C
III.3.a

$$\frac{R^3}{T^2} = K$$

39
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458

If R is expressed in metres and T in seconds, what is the derived unit for K?

F1
A4

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Scoring Scheme	Answer
✓	$\frac{m^3}{s^2}$

6

S17C
III.3.a

S 39

F1
A8

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How many days would the moon take to complete one full revolution around the earth if its distance from the earth were increased to four times its present distance? (Assume that it takes 28 d to complete one revolution at its present distance.)

Scoring Scheme	Answer	
✓	$R_2 = 4R_1$	$T_1 = 28$ d
✓	$\frac{R^3}{T^2} = K$	
✓	$\frac{R_1^{\ 3}}{T_1^{\ 2}} = \frac{R_2^{\ 3}}{T_2^{\ 2}}$	
✓	$= \frac{(4R_1)^3}{T_2^{\ 2}}$	
✓	$= \frac{64\ R_1^{\ 3}}{T_2^{\ 2}}$	
✓	$T_2^{\ 2} = 64\ T_1^{\ 2}$	
✓	$T_2 = 8\ T_1$	
✓	$= 8\ (28\ \text{d})$	
✓ ✓	$= 224$ d	
✓	One complete revolution would take 224 d.	

7

S17C
III.3.a

S 39

F1
A8
A3

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An asteroid is five times as far from the sun as the earth. How many earth years are required for the asteroid to make one complete circular orbit around the sun? (Express your answer correct to two significant digits.)

Scoring Scheme | Answer

Let R_{ES} be the distance between the earth and the sun

R_{AS} be the distance between the asteroid and the sun

✓ T_E be the period of revolution for the earth

T_A be the period of revolution for the asteroid

$R_{AS} = 5\ R_{ES}$ $\qquad T_E = 1\text{ a}$

✓ $\frac{R^3}{T^2} = \text{K}$

✓ $\frac{R_{ES}{}^3}{T_E{}^2} = \frac{R_{AS}{}^3}{T_A{}^2}$

✓ $= \frac{(5\ R_{ES})^3}{T_A{}^2}$

✓ $= \frac{5^3\ R_{ES}{}^3}{T_A{}^2}$

✓ $T_A{}^2 = 5^3\ T_E{}^2$

✓ $T_A = \sqrt{125}\ T_E$

✓ $= \sqrt{125}\ (1\text{ a})$

$= \sqrt{125}\text{ a}$

✓ ✓ $= 11\text{ a}$

✓ The time required for the asteroid to complete one revolution is 11 a.

8

S17C
III.3.b

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F1
A8
A3

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A careless 100 kg astronaut finds himself stranded 70 m away from his 7000 kg space ship with the end of his safety line out of reach. He hopes that the gravitational force between the space ship and himself will pull him back in. ($G = 6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$)

(a) What is the magnitude of the gravitational force on the astronaut at this distance?

(b) Describe the change in the gravitational force as the astronaut moves closer to the space ship. Give an example to clarify your answer.

Scoring Scheme	Answer
√	$m_1 = 100$ kg $\quad r = 70$ m $m_2 = 7000$ kg $\quad G = 6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2$
√	(a) $F = G\dfrac{m_1 m_2}{r^2}$
√	$= \dfrac{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)\ (100\ \text{kg})\ (7 \times 10^3\ \text{kg})}{(70\ \text{m})^2}$
√ √	$= 9.5 \times 10^{-9}$ N
√	The magnitude of the gravitational force is 9.5×10^{-9} N.
√	(b) The gravitational force will vary
√	inversely as the square of the
√	distance between the astronaut and
√	the space ship. If the
√	separation halves, the force will
√	be four times as great.

9

S17C
III.3.a

The mass M of the planet Jupiter may be determined from observations of one of its moons called Io. Io has a mass m and is assumed to have a circular orbit of radius r.

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(a) Write an equation expressing Newton's Law of Universal Gravitation as it relates to the force F between Jupiter and Io.

F1
A8
A3

(b) Using the equation for Newton's Law of Universal Gravitation and the formula for centripetal force, derive Kepler's third law relating the radius and period for circular orbits.

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(c) For the moon Io, astronomical measurements give the radius of its orbit to be 4.2×10^{8} m and the period of revolution to be 1.5×10^{5} s. Calculate the mass of Jupiter. (The gravitational constant may be taken as $6.7 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$.)

Scoring Scheme	Answer
✓	(a) $F = G \dfrac{Mm}{r^2}$
✓	(b) $F = m \dfrac{v^2}{r} = m \dfrac{4\pi^2 r}{T^2}$
✓	$\dfrac{m 4\pi^2 r}{T^2} = G \dfrac{Mm}{r^2}$
✓	$\dfrac{r^3}{T^2} = \dfrac{GM}{4\pi^2}$
✓	but $\dfrac{GM}{4\pi^2}$ is constant
✓	$\therefore \dfrac{r^3}{T^2} = K$
✓	(c) $\dfrac{GM}{4\pi^2} = \dfrac{r^3}{T^2}$
✓	$M = \dfrac{4\pi^2 r^3}{GT^2}$
✓	$= \dfrac{4\,(3.14)^2\,(4.2 \times 10^{8}\ \mathrm{m})^3}{(6.7 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2})\,(1.5 \times 10^{5}\ \mathrm{s})^2}$
✓ ✓	$= 1.9 \times 10^{27}$ kg
✓	The mass of Jupiter is 1.9×10^{27} kg.

IMPULSE AND CONSERVATION OF MOMENTUM

1 A 0.050 kg golf ball is at rest on a tee when it is struck by a golf club. What impulse would cause it to leave the tee with a velocity of 40 m/s at an angle of 30° above the horizontal?

S17C
III.4.a

42

A3
F1
A8

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Scoring Scheme	Answer
✓	$m = 0.050$ kg $\quad \vec{v}_i = 0 \quad \vec{v}_f = 40$ m/s, 30° above horizontal
✓	Impulse = $m\,\Delta\vec{v}$
✓ ✓	= 0.05 kg (40 m/s [30° above horiz.] - 0)
✓ ✓ ✓	= 2.0 kg·m/s [30° above horiz.] <u>or</u> 2.0 N·s [30° above horiz.]
✓	The impulse is 2.0 N·s at an angle of 30° above the horizontal.

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S17C
III.4.a

42

F1
A8

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A 0.50 kg soccer ball was moving north toward a player at a speed of 7.5 m/s when the player kicked the ball so that it rebounded at a velocity of 11 m/s south. If his toe was in contact with the ball for 0.015 s, determine the average force applied to the ball by the kicker.

Scoring Scheme	Answer
√	Let (+) represent north (-) represent south
√	$m = 0.50$ kg $\vec{v}_i = 7.5$ m/s $\Delta t = 0.015$ s $\vec{v}_f = -11$ m/s
√	$\vec{F} = \dfrac{m(\vec{v}_f - \vec{v}_i)}{\Delta t}$
√	$= \dfrac{0.50 \text{ kg } (-11 \text{ m/s} - 7.5 \text{ m/s})}{0.015 \text{ s}}$
√	$= \dfrac{0.50\ (-18.5)}{0.015} \dfrac{\text{kg}\cdot\text{m}}{\text{s}^2}$
√	$= -617$ N
√ √ √	$= 6.2 \times 10^2$ N south
√	The average force applied was 6.2×10^2 N south.

3 A 5.0 kg mass A, moving at 2.0 m/s to the right, has a head-on collision with a 3.0 kg mass B, moving at

S17C 1.0 m/s to the left. The 3.0 kg mass bounces back

III.4.a with a velocity of 2.0 m/s to the right.

42 Find the velocity of the 5.0 kg mass after impact.

F1
A8

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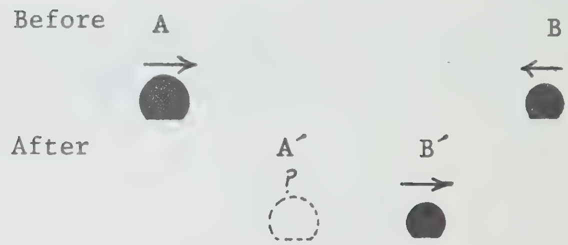
Scoring Scheme	Answer
✓	Suitable sketch



✓	Let (+) represent 'to the right'
	(´) represent 'after the impact'
✓	$m_A = 5.0$ kg $\quad\quad \vec{v}_A = +2.0$ m/s
✓	$m_B = 3.0$ kg $\quad\quad \vec{v}_B = -1.0$ m/s $\quad\quad \vec{v}_B{}' = +2.0$ m/s
✓	Momentum is conserved
✓	$\vec{p}_T = \vec{p}_T{}'$
✓	$m_A \vec{v}_A + m_B \vec{v}_B = m_A \vec{v}_A{}' + m_B \vec{v}_B{}'$
✓	$(5.0 \text{ kg})(2.0 \text{ m/s}) + (3.0 \text{ kg})(-1.0 \text{ m/s})$
	$= (5.0 \text{ kg})\, \vec{v}_A{}' + (3.0 \text{ kg})(2.0 \text{ m/s})$
✓	$10 \text{ kg·m/s} - 3.0 \text{ kg·m/s} = (5.0 \text{ kg})\, \vec{v}_A{}' + 6.0 \text{ kg·m/s}$
✓	$(5.0 \text{ kg})\, \vec{v}_A{}' = 1.0 \text{ kg·m/s}$
✓ ✓	$\vec{v}_A{}' = 0.20$ m/s
✓	The velocity of the 5.0 kg mass after impact is 0.2 m/s to the right.

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S17C
III.4.a
42
F1
A8
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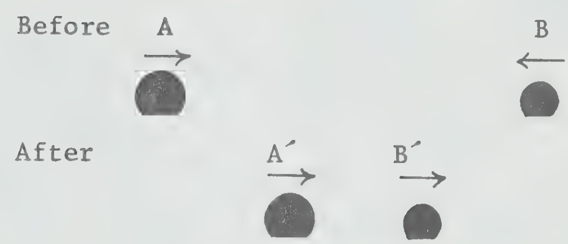
A 5.0 kg mass A, moving at 2.0 m/s to the right, has a head-on collision with a 3.0 kg mass B, moving at 1.0 m/s to the left. After the collision the 5.0 kg mass has a velocity of 0.20 m/s to the right and the 3.0 kg mass bounces back with a velocity of 2.0 m/s to the right.

Find the average force that mass B exerts on mass A if the impact lasts for 0.050 s.

Scoring Scheme	Answer
✓	Suitable sketch



Scoring Scheme	Answer		
✓	Let (+) represent 'to the right'		
	(´) represent 'after the impact'		
✓	$m_A = 5.0$ kg	$\vec{v}_A = +2.0$ m/s	$\vec{v}_A{}' = +0.20$ m/s
✓	$m_B = 3.0$ kg	$\vec{v}_B = -1.0$ m/s	$\vec{v}_B{}' = +2.0$ m/s
	$t = 0.050$ s		
✓	$F = ma$		
✓	$= m \dfrac{(v_f - v_i)}{t}$		
✓	$= \dfrac{5.0 \text{ kg } (0.20 - 2.0) \text{ m/s}}{0.050 \text{ s}}$		
✓	$= \dfrac{5.0\ (-1.8)}{0.050}$ N		
✓ ✓ ✓	$= -1.8 \times 10^2$ N		
✓ ✓	The average force that mass B exerts on mass A is 1.8×10^2 N to the left.		

5

S17C
III.5.b

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53

F1
A8

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A 3.0 kg laboratory cart moves along a frictionless horizontal surface at 4.0 m/s. As the cart moves past, a student drops a 1.0 kg brick from rest onto the cart. Assume that the brick is dropped from a negligible height. The horizontal speed of the 'cart with brick' system after the collision is 3.0 m/s.

Show numerically that kinetic energy is <u>not</u> conserved in this collision.

Scoring Scheme	Answer
√	Suitable sketch 
	m_c = mass of the cart = 3.0 kg
√	m_b = mass of the brick = 1.0 kg
	v_c = initial horizontal velocity of the cart = 4.0 m/s
	v_b = initial horizontal velocity of the brick = 0
	v_f = final horizontal velocity of the cart and the brick = 3.0 m/s
√	$E_{k_i} = \frac{1}{2} m_c v_c^2 + \frac{1}{2} m_b v_b^2$
√	$= \frac{1}{2}(3.0\text{ kg})(4.0\text{ m/s})^2 + 0$
√ √	$= 24\text{ J}$
√	$E_{k_f} = \frac{1}{2}(m_c + m_b) v_f^2$
√	$= \frac{1}{2}(3.0\text{ kg} + 1.0\text{ kg})(3.0\text{ m/s})^2$
√ √	$= 18\text{ J}$
√	The total kinetic energy before the interaction is 24 J.
√	The total kinetic energy after the interaction is 18 J.
√	Therefore, kinetic energy has not been conserved.

6

S17C
III.5.b

42
53

F1
A8

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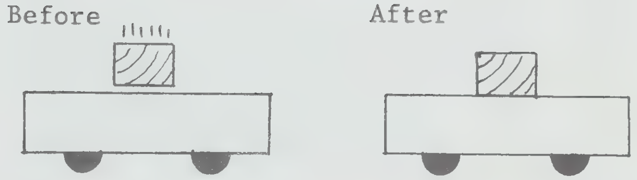
A 3.0 kg laboratory cart moves along a frictionless horizontal surface at 4.0 m/s. As the cart moves past, a student drops a 1.0 kg brick from rest onto the cart. Assume that the brick is dropped from a negligible height.

Calculate the speed of the 'cart with brick' system.

Scoring Scheme	Answer
✓	Suitable Sketch



m_c = mass of the cart = 3.0 kg

✓ m_b = mass of the brick = 1.0 kg

$\vec{v}_c$ = initial horizontal velocity of the cart = 4.0 m/s

$\vec{v}_b$ = initial horizontal velocity of the brick = 0

$\vec{v}_f$ = final horizontal velocity of the cart and the brick

✓ Momentum is conserved

✓ $m_c \vec{v}_c + m_b \vec{v}_b = (m_c + m_b) \vec{v}_f$

✓ $(3.0 \text{ kg})(4.0 \text{ m/s}) + (1.0 \text{ kg})(0) = (3.0 \text{ kg} + 1.0 \text{ kg}) \vec{v}_f$

$12 \text{ kg·m/s} = 4.0 \text{ kg } \vec{v}_f$

✓ ✓ $\vec{v}_f = 3.0 \text{ m/s}$

✓ The final horizontal speed of the 'cart with brick' system is 3.0 m/s.

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S17C
III.4.a

42

F2
A8

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In a cloud chamber experiment a particle originally at rest disintegrates. The information below gives the cloud chamber tracks and related data for two particles that were detected.

<u>Particle 1</u>

$m_1 = 5 \times 10^{-26}$ kg

$\vec{v}_1 = 8 \times 10^{6}$ m/s [N]

<u>Particle 2</u>

$m_2 = 3 \times 10^{-26}$ kg

$\vec{v}_2 = 1 \times 10^{7}$ m/s [E]

DIAGRAM NOT TO SCALE

(a) Determine the momentum of particle 1.

(b) Determine the momentum of particle 2.

(c) Assume that a third particle was also emitted, but was not detected. Determine the momentum of the third particle.

<u>Scoring Scheme</u>

<u>Answer</u>

$m_1 = 5 \times 10^{-26}$ kg $\qquad$ $m_2 = 3 \times 10^{-26}$ kg

$\vec{v}_1 = 8 \times 10^{6}$ m/s [N] $\qquad$ $\vec{v}_2 = 1 \times 10^{7}$ m/s [E]

✓ (a) $\vec{p}_1 = m_1\vec{v}_1$

✓ $= (5 \times 10^{-26}\ \text{kg})(8 \times 10^{6}\ \text{m/s [N]})$

✓ ✓ ✓ $= 4 \times 10^{-19}$ kg·m/s [N]

✓ The momentum of particle 1 is 4×10^{-19} kg·m/s [N]

✓ (b) $\vec{p}_2 = m_2\vec{v}_2$

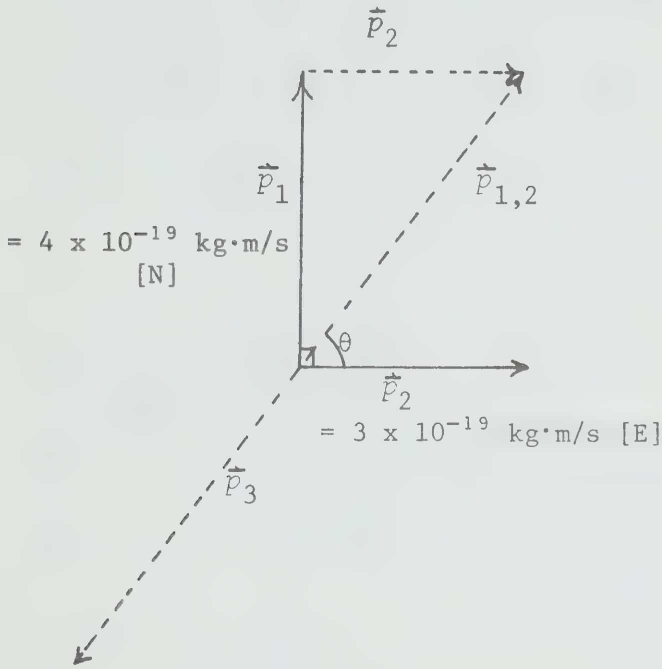
✓ $= (3 \times 10^{-26}\ \text{kg})(1 \times 10^{7}\ \text{m/s [E]})$

✓ ✓ ✓ $= 3 \times 10^{-19}$ kg·m/s [E]

✓ The momentum of particle 2 is 3×10^{-19} kg·m/s [E].

Scoring Scheme	Answer
	(c) $\vec{p}_{1,2} = \vec{p}_1 + \vec{p}_2$
	$\vec{p}_1 \perp \vec{p}_2$ and $\vec{v}_1 \perp \vec{v}_2$

Sketch or Vector Diagram



Vector p_1

✓	$\vec{p}_1$ labelled
✓	magnitude labelled
✓	direction labelled

Vector p_2

✓	$\vec{p}_2$ labelled
✓	magnitude labelled
✓	direction labelled

Scoring Scheme	Answer
	Vector $p_{1,2}$
✓	$p_{1,2}$ labelled
✓	θ labelled
	Vector Orientation
✓ ✓	orientation of p_1 and p_2 to each other
✓	orientation of $p_{1,2}$ to the other two
	Solution I: Pythagorean Theorem
✓	$p_{1,2}{}^2 = p_1{}^2 + p_2{}^2$
✓	$= (4.0 \times 10^{-19}\ \mathrm{kg \cdot m/s})^2 + (3.0 \times 10^{-19}\ \mathrm{kg \cdot m/s})^2$
	$= (4.0^2 + 3.0^2)\ (10^{-19}\ \mathrm{kg \cdot m/s})^2$
	$p_{1,2} = \sqrt{25}\ (10^{-19}\ \mathrm{kg \cdot m/s})$
✓ ✓	$= 5.0 \times 10^{-19}\ \mathrm{kg \cdot m/s}$
✓	$\tan\theta = \dfrac{p_1}{p_2}$
✓	$= \dfrac{4.0 \times 10^{-19}\ \mathrm{kg \cdot m/s}}{3.0 \times 10^{-19}\ \mathrm{kg \cdot m/s}}$
✓	$= 1.333$
✓	$\theta = 53°$
✓ ✓ ✓	$\vec{p}_{1,2} = 5.0 \times 10^{-19}\ \mathrm{kg \cdot m/s}$ [E 53° N]
✓	The momentum before the particle disintegrates is 0.
✓	Momentum is conserved.
✓	$\vec{p}_1 + \vec{p}_2 + \vec{p}_3 = 0$
✓	$\vec{p}_{1,2} + \vec{p}_3 = 0$
✓	$\vec{p}_3 = -\vec{p}_{1,2}$
✓ ✓ ✓	The momentum of particle 3 is $5.0 \times 10^{-19}\ \mathrm{kg \cdot m/s}$ [W 53° S].

Scoring Scheme	Answer	
	Solution II: Vector Drawing	
✓	indication of scale	Scale: Let 1 cm represent 1.0×10^{-19} kg·m/s
✓	appropriateness of scale	
✓	constructed length and direction of $\vec{p}_1$	4 cm [N]
✓	constructed length and direction of $\vec{p}_2$	3 cm [E]
✓	measured length of $\vec{p}_{1,2}$	5 cm
✓	determination of $\vec{p}_{1,2}$	$5 \times 1.0 \times 10^{-19}$ kg·m/s
		$= 5.0 \times 10^{-19}$ kg·m/s
✓	measured direction of θ	53°
✓	direction of $\vec{p}_{1,2}$	[E 53° N]
✓ ✓ ✓	$\vec{p}_{1,2} = 5.0 \times 10^{-19}$ kg·m/s [E 53° N]	
✓	The momentum before the particle disintegrates is 0.	
✓	Momentum is conserved.	
✓	$\vec{p}_1 + \vec{p}_2 + \vec{p}_3 = 0$	
✓	$\vec{p}_{1,2} + \vec{p}_3 = 0$	
✓	$\vec{p}_3 = -\vec{p}_{1,2}$	
✓ ✓ ✓	The momentum of particle 3 is 5.0×10^{-19} kg·m/s [W 53° S].	

8

S17C
III.4.a

For items 1-4, determine the <u>area</u> of the shaded portion of each graph and place your answer in the space provided. Include the correct SI units, but ignore significant figures.

S 42

F1 Scoring Scheme
A11
A7

✓ ✓

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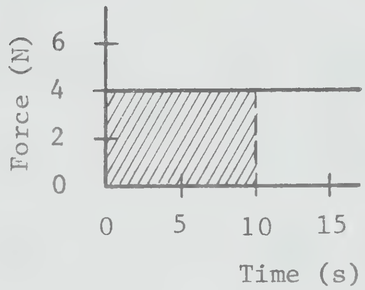
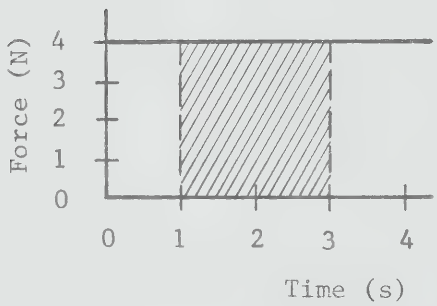
Answer

(1)



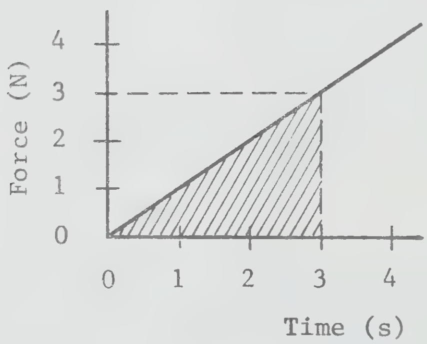
____________ (40 N·s) or (40 $\frac{kg \cdot m}{s}$)

(2) ✓ ✓



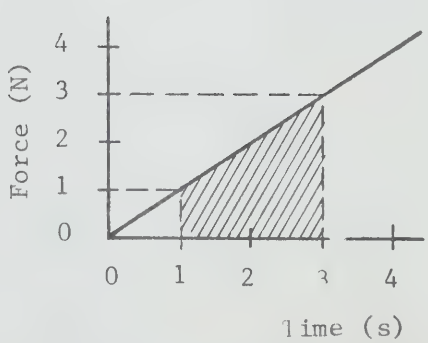
____________ (8 N·s) or (8 $\frac{kg \cdot m}{s}$)

(3) ✓ ✓



____________ (4.5 N·s) or (4.5 $\frac{kg \cdot m}{s}$)

(4) ✓ ✓



____________ (4 N·s) or (4 $\frac{kg \cdot m}{s}$)

9

S17C
III.4.a

For items 1-4, determine the area of the shaded portion of each graph and place your answer in the space provided. Include the correct SI units, but ignore significant figures.

S 42

F1 Scoring Scheme

All

A7 ✓ ✓

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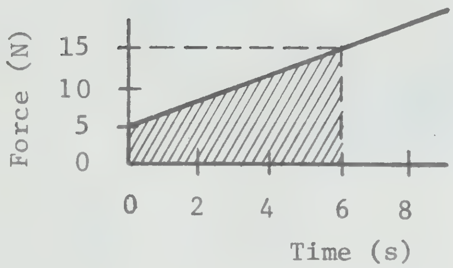
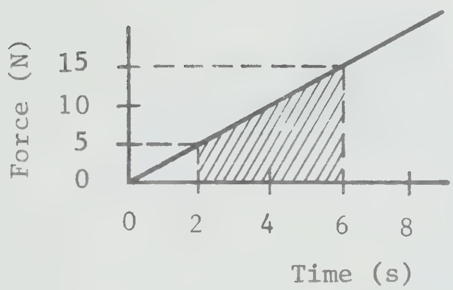
Answer

(1)



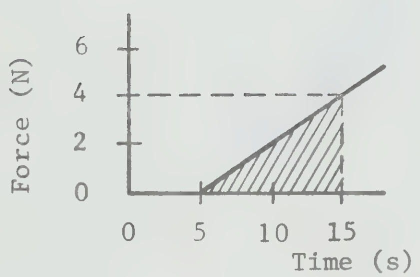
_______________ (60 N·s) or (60 $\frac{kg \cdot m}{s}$)

✓ ✓ (2)



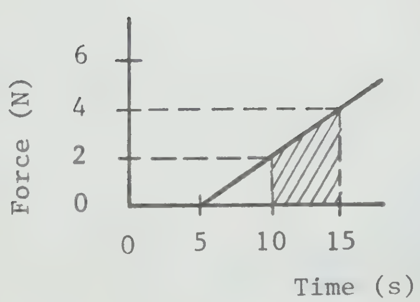
_______________ (40 N·s) or (40 $\frac{kg \cdot m}{s}$)

✓ ✓ (3)



_______________ (20 N·s) or (20 $\frac{kg \cdot m}{s}$)

✓ ✓ (4)



_______________ (15 N·s) or (15 $\frac{kg \cdot m}{s}$)

10 For items 1-5, determine the area of the shaded portion of each graph and place your answer in the space provided. Include the correct SI units, but ignore significant figures.

S17C
III.4.a

S 42

F1 Scoring Scheme
A11
A7

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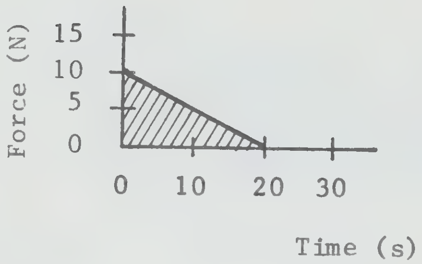
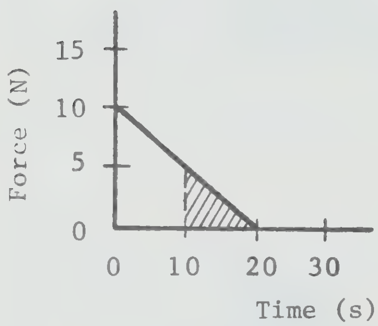
Answer

√ √ (1)



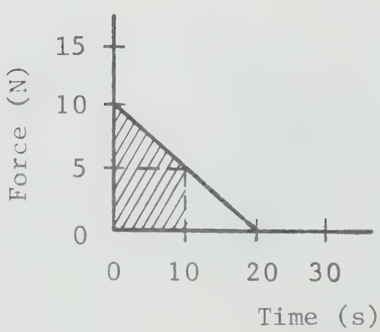
__________ (100 N·s) or (100 $\frac{kg \cdot m}{s}$)

√ √ (2)



__________ (25 N·s) or (25 $\frac{kg \cdot m}{s}$)

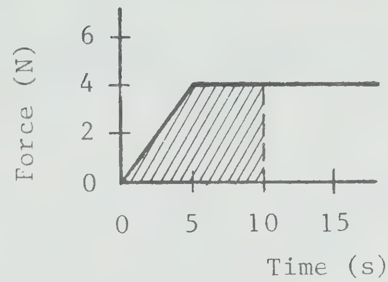
√ √ (3)



__________ (75 N·s) or (75 $\frac{kg \cdot m}{s}$)

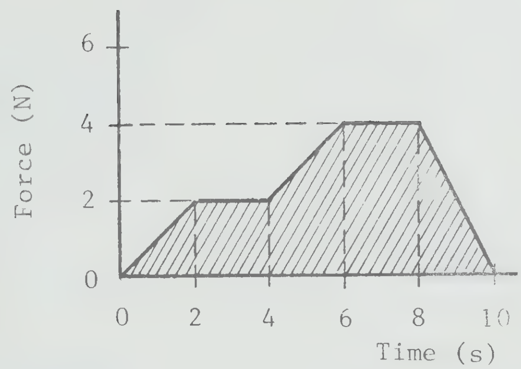
Scoring Scheme | Answer

✓ ✓ (4)



(30 N·s) or (30 $\frac{kg \cdot m}{s}$)

✓ ✓ (5)



(24 N·s) or (24 $\frac{kg \cdot m}{s}$)

11 A 6.0 kg ball travelling at 5.0 m/s collides with a stationary 9.0 kg ball. After collision the 6.0 kg ball moves off at 4.0 m/s and the 9.0 kg ball moves off in a direction perpendicular to that of the 6.0 kg ball.

S17C
III.4.b

44

What is the speed of the 9.0 kg ball after the collision?

F1
A8

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Scoring Scheme

Answer

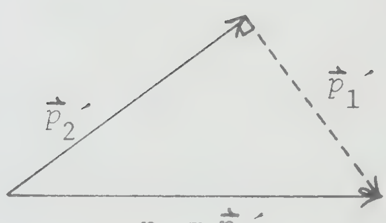
$m_1 = 9.0$ kg $\qquad m_2 = 6.0$ kg

$v_1 = 0 \qquad v_2 = 5.0$ m/s

v_1' is $\perp$ $v_2' \qquad v_2' = 4.0$ m/s

$\therefore\ p_1'$ is $\perp$ p_2'

Sketch



✓ p_1' labelled

✓ p_2' labelled

✓ $p_1' \perp p_2'$

✓ p_T and/or p_T' labelled

✓ $\vec{p}_T = \vec{p}_T\,'$

✓ $\quad = \vec{p}_1\,' + \vec{p}_2\,'$

✓ $|p_T| = |m_1v_1 + m_2v_2|$

✓ $\quad = 0 + (6.0\text{ kg})\ (5.0\text{ m/s})$

✓ ✓ $\quad = 30\text{ kg·m/s}$

✓ $|p_2'| = |m_2v_2'|$

✓ $\quad = (6.0\text{ kg})\ (4.0\text{ m/s})$

✓ ✓ $\quad = 24.0\text{ kg·m/s}$

✓ $\vec{p}_T = \vec{p}_1\,' + \vec{p}_2\,'$ and $\vec{p}_1\,' \perp \vec{p}_2\,'$

Scoring Scheme	Answer	
	Solution I: Pythagorean Theorem	
✓	$(p_T')^2 = (p_1')^2 + (p_2')^2$	
✓	$(p_1')^2 = (p_T')^2 - (p_2')^2$	
✓	$= (30\ \mathrm{kg{\cdot}m/s})^2 - (24\ \mathrm{kg{\cdot}m/s})^2$	
✓	$= (900 - 576)\ (\mathrm{kg{\cdot}m/s})^2$	
✓	$= 324\ (\mathrm{kg{\cdot}m/s})^2$	
✓	$p_1' = \sqrt{324}\ \mathrm{kg{\cdot}m/s}$	
✓ ✓	$= 18\ \mathrm{kg{\cdot}m/s}$	
✓	$p_1' = m_1 v_1'$	
✓	$m_1 v_1' = 18\ \mathrm{kg{\cdot}m/s}$	
✓	$v_1' = \dfrac{18\ \mathrm{kg{\cdot}m/s}}{9.0\ \mathrm{kg}}$	
✓ ✓	$= 2.0\ \mathrm{m/s}$	
✓	The speed of the 9.0 kg ball after collision is 2.0 m/s.	
	Solution II: Scale Drawing	
✓	scale designation	Scale: Let 1 cm represent 6 kg·m/s
✓	appropriateness of scale	
✓	constructed length of p_2'	4 cm
✓	constructed direction of p_1' (extended)	[90° to p_2']
✓	constructed length of p_T'	5 cm
✓	measured length of p_1'	3 cm
✓	determination of p_1'	3 x 6 kg·m/s
✓		= 18 kg·m/s

Scoring Scheme	Answer
✓	$p_1' = m_1v_1'$
✓	$m_1v_1' = 18\ \text{kg·m/s}$
✓	$v_1' = \dfrac{18\ \text{kg·m/s}}{9.0\ \text{kg}}$
✓ ✓	$= 2.0\ \text{m/s}$
✓	The speed of the 9.0 kg ball after collision is 2.0 m/s.

12

S17C
III.4.b

44

F1
A8

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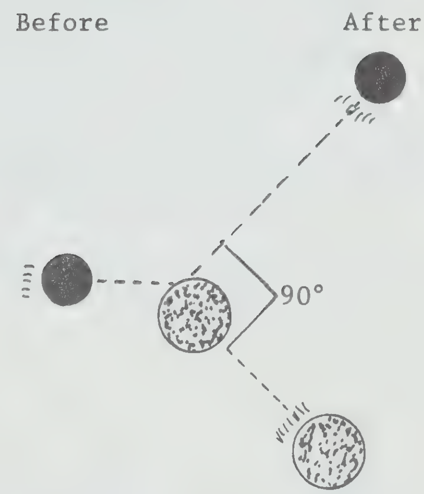
A 6.0 kg ball travelling at 5.0 m/s collides with a stationary 9.0 kg ball. After collision the 6.0 kg ball moves off at 4.0 m/s and the 9.0 kg ball moves off in a direction perpendicular to that of the 6.0 kg ball with a speed of 2.0 m/s.

How much kinetic energy was lost in the collision?

Scoring Scheme — Answer

✓ Suitable sketch



✓ $m_1 = 9.0\text{ kg}$ $\quad v_1 = 0$ $\quad v_1{'} = 2.0\text{ m/s}$ $\perp v_2{'}$

$m_2 = 6.0\text{ kg}$ $\quad v_2 = 5.0\text{ m/s}$ $\quad v_2{'} = 4.0\text{ m/s}$

✓ $\Delta E_k = E_{k_f} - E_{k_i}$

✓ $= \frac{1}{2} m_1 (v_1{'})^2 + \frac{1}{2} m_2 (v_2{'})^2 - \frac{1}{2} m_2 v_2{}^2$

✓ $= \frac{1}{2}(9.0\text{ kg})(2.0\text{ m/s})^2 + \frac{1}{2}(6.0\text{ kg})(4.0\text{ m/s})^2 - \frac{1}{2}(6.0\text{ kg})(5.0\text{ m/s})^2$

✓ ✓ ✓ $= 18\text{ J} + 48\text{ J} - 75\text{ J}$

✓ ✓ $= -9.0\text{ J}$

✓ ✓ The loss in kinetic energy is 9.0 J.

WORK AND

KINETIC ENERGY

1 A stone of mass 10 kg has a velocity of 12 m/s south. A machine exerts a constant unbalanced force on the stone for 5.0 s, giving it a final velocity of 2.0 m/s north.

S17C
III.5.a

47
42

F1
A8

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(a) Calculate the impulse imparted to the stone.

(b) What is the magnitude and direction of the force applied by the machine to the stone?

(c) Calculate the work done <u>by</u> the machine on the stone.

Scoring Scheme	Answer	
✓	Let (+) represent north.	
✓	$m = 10$ kg	$\vec{v}_i = -12$ m/s
✓	$\Delta t = 5.0$ s	$\vec{v}_f = +2.0$ m/s

✓ (a) Impulse $= \vec{F}\Delta t = m\Delta\vec{v}$

$= m(\vec{v}_f - \vec{v}_i)$

✓ $= 10 \text{ kg } [+2.0 \text{ m/s} - (-12 \text{ m/s})]$

$= 10\ (14) \text{ kg}\cdot\text{m/s}$

✓ ✓ ✓ $= +1.4 \times 10^2 \text{ kg}\cdot\text{m/s}$

✓ ✓ The impulse is 1.4×10^2 kg·m/s north.

Scoring Scheme	Answer
✓	(b) $\vec{F} = \frac{\text{Impulse}}{\Delta t}$
✓	$= \frac{+140\ \text{kg·m/s}}{5.0\ \text{s}}$
✓ ✓	$= +28\ \text{N}$
✓ ✓	The applied force is 28 N north.
	(c) The machine exerts a force on the stone opposite to the direction of motion of the stone while it slows down. The machine exerts a force in the same direction as the stone moves while the stone speeds up.
✓ ✓	The machine does work on the stone only while the stone speeds up.
	Consider the interval during which the stone speeds up.
✓	$v_{\text{i}} = 0$
	$v_{\text{f}} = 2.0\ \text{m/s}$
✓	$W = \Delta E_{\text{k}}$
✓	$= \frac{1}{2} m(v_{\text{f}}^2 - v_{\text{i}}^2)$
✓	$= \frac{1}{2}(10\ \text{kg})[(2.0\ \text{m/s})^2 - 0]$
	$= 5.0\ [4.0]\ \text{kg·m}^2/\text{s}^2$
	$= 20\ \text{kg·m}^2/\text{s}^2$
✓ ✓	$= 20\ \text{J}$
✓	The work done by the machine on the stone is 20 J.

2	A body of mass 20 kg, moving under the action of a constant unbalanced force, covers two consecutive distances of 150 cm along its path in 3.0 s and 2.0 s respectively.
S17A I.2.b S17C III.1.d	Calculate the magnitude of the acceleration of the body.
51 35 19	
F1 A8	
*** *** –	

Scoring Scheme	Answer	
	$m = 20$ kg	F is constant
✓	$d_1 = 150$ cm	$\Delta t_1 = 3.0$ s
	$d_2 = 150$ cm	$\Delta t_2 = 2.0$ s
✓	$a = \dfrac{v_2 - v_1}{t_2 - t_1}$	
✓ ✓ ✓	Since force is constant, acceleration is constant, and v_1 occurs at the midpoint of the time interval Δt_1. Similarily for v_2.	
✓	$v_1 = \dfrac{\Delta d_1}{\Delta t_1}$	
✓	$= \dfrac{150 \text{ cm}}{3.0 \text{ s}}$	
✓ ✓	$= 50$ cm/s	
✓ ✓	$v_2 = \dfrac{\Delta d_2}{\Delta t_2} = \dfrac{150 \text{ cm}}{2.0 \text{ s}} = 75$ cm/s	
✓	t_1 = midpoint of the interval $\Delta t_1 = \frac{1}{2}(\Delta t_1)$	
✓ ✓	$= 1.5$ s	

Scoring Scheme	Answer
✓	t_2 = midpoint of the interval $\Delta t_2 = \Delta t_1 + \frac{1}{2}(\Delta t_2)$
	$= 3.0\ \text{s} + \frac{1}{2}(2.0\ \text{s})$
✓ ✓	$= 4.0\ \text{s}$
✓	$a = \dfrac{75\ \text{cm/s} - 50\ \text{cm/s}}{4.0\ \text{s} - 1.5\ \text{s}}$
	$= \dfrac{25\ \text{cm/s}}{2.5\ \text{s}}$
✓ ✓	$= 10\ \text{cm/s}^2$
	or
	$= 0.10\ \text{m/s}^2$
✓ ✓	The magnitude of the acceleration is $10\ \text{cm/s}^2$ or $0.10\ \text{m/s}^2$.

3	A body of mass 20 kg, moving under the action of a constant unbalanced force, covers two consecutive distances of 150 cm along its path in 3.0 s and 2.0 s respectively. It has an acceleration of 0.10 m/s^2.
S17A I.2.b S17C III.1.d	(a) Calculate the magnitude of the unbalanced force acting on the body.
51 35 19	(b) Calculate the increase in kinetic energy of the body during the 3.0 s time interval.
F1 A8	
*** *** --	

Scoring Scheme	Answer	
	m = 20 kg	a = 0.10 m/s^2
✓	F is constant	
	d_1 = 150 cm	Δt_1 = 3.0 s
	d_2 = 150 cm	Δt_2 = 2.0 s
✓	(a) $F = ma$	
✓	$= 20 \text{ kg} \times 0.10 \text{ m/s}^2$	
✓ ✓	$= 2.0 \text{ N}$	
✓	An unbalanced force of 2.0 N acts on the body.	
✓	(b) $\Delta E_k = F \cdot d$	
✓	$= 2.0 \text{ N} \times 150 \text{ cm}$	
✓	$= 2.0 \text{ N} \times 1.5 \text{ m}$	
✓ ✓	$= 3.0 \text{ J}$	
✓	The increase in kinetic energy of the body during the 3.0 s interval is 3.0 J.	

4

S17C
III.5.a

53
47

F1
A8

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A force of 15 N acts on a mass of 4.0 kg initially at rest on a frictionless table. The mass travels 7.5 m during the time that the force acts.

(a) How much work is done by the force on the mass?

(b) What is the final speed of the mass?

Scoring Scheme	Answer	
√	$F = 15$ N	$v_i = 0$
	$m = 4.0$ kg	$d = 7.5$ m
√	(a) $W = Fd$	
√	$= (15\text{ N})\ (7.5\text{ m})$	
	$= 112.5$ J	
√ √	$= 1.1 \times 10^2$ J	
√	The work done is 1.1×10^2 J.	
√	(b) $W = \Delta E_k$	
√	$= \frac{1}{2}\, m\, v_f^{\ 2} - \frac{1}{2}\, m\, v_i^{\ 2}$	
√ √	$1.1 \times 10^2\text{ J} = \frac{1}{2}\,(4.0\text{ kg})\,(v_f^{\ 2} - 0)$	
√	$v_f^{\ 2} = 55$ J/kg	
√ √	$v_f = \pm\ 7.4$ m/s	
√	The final speed is 7.4 m/s.	

5

S17C
III.5.a

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47

F1
A8

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A force of 15 N acts on a mass of 4.0 kg initially at rest on a frictionless table. The mass reaches a final speed of 7.4 m/s.

(a) What is the magnitude of the impulse imparted on the mass?

(b) Determine the time interval during which the force acts.

Scoring Scheme	Answer
√	$F = 15$ N $v_i = 0$ $m = 4.0$ kg $v_f = 7.4$ m/s
√	(a) Impulse $= F\Delta t = m\Delta v$
√	$= (4\ \text{kg})\ (7.4\ \text{m/s} - 0)$
√	$= 30\ \text{kg}\cdot\text{m/s}$
√ √	$= 30\ \text{N}\cdot\text{s}$
√	The magnitude of the impulse is 30 N·s.
√	(b) Impulse $= F\Delta t$
√	$30\ \text{kg}\cdot\text{m/s} = 15\ \text{N}\ \Delta t$
√ √	$\Delta t = 2.0$ s
√	The force acts for a time interval of 2.0 s.

6

S17C
III.5.c

54

A8

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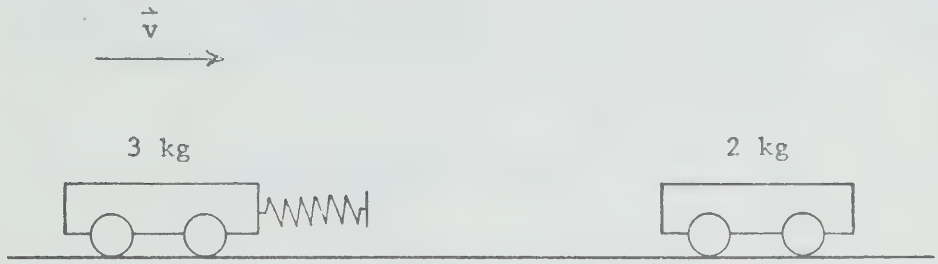
The diagram below represents two carts about to undergo an elastic interaction on a level surface.



Complete each of the following statements with a correct phrase selected from these choices:

greater than
equal to
less than
independent of

(a) At minimum separation, the speed of the 3 kg mass is _______________ the speed of the 2 kg mass.

(b) At any instant during the interaction, the magnitude of the acceleration of the 3 kg mass is _______________ that of the 2 kg mass.

(c) From the beginning to the end of the interaction, the magnitude of the impulse applied to the 3 kg mass is _______________ that applied to the 2 kg mass.

(d) From the beginning of the interaction up to minimum separation, the loss in kinetic energy of the 3 kg mass is _______________ the gain in kinetic energy of the 2 kg mass.

Scoring Scheme	Answer
√	(a) equal to
√	(b) less than
√	(c) equal to
√	(d) greater than

7 A cart having a mass of 4.0 kg is travelling at 9.0 m/s horizontally to the right. It collides with a 2.0 kg cart travelling at 3.0 m/s in the same direction. The collision is cushioned by a perfectly elastic bumper, and friction is negligible.

S17C
III.5.c

54
43

F1
A8

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(a) Determine the speed of the carts when they are at minimum separation.

(b) Calculate the potential energy stored in the bumper at minimum separation.

Scoring Scheme	Answer
√	Let (+) represent "to the right".
√	$m_1 = 4.0$ kg $m_2 = 2.0$ kg $\vec{v}_1 = +9.0$ m/s $\vec{v}_2 = +3.0$ m/s
√	(a) At minimum separation both carts have the same velocity.
√	Let $\vec{V}$ represent the velocity at minimum separation.
√	$\vec{p}_T = \vec{p}_T$ (at minimum separation)
√	$m_1\vec{v}_1 + m_2\vec{v}_2 = (m_1 + m_2)\,\vec{V}$
√	$(4.0\text{ kg})(9.0\text{ m/s}) + (2.0\text{ kg})(3.0\text{ m/s}) = (4.0\text{ kg} + 2.0\text{ kg})\,\vec{V}$
	$36.0\text{ kg·m/s} + 6.0\text{ kg·m/s} = (6.0\text{ kg})\,\vec{V}$
√ √	$\vec{V} = +7.0$ m/s
√ √	The speed of the carts at minimum separation is 7.0 m/s right.
√	(b) $E_{k_T} = \frac{1}{2}\,m_1v_1^{\,2} + \frac{1}{2}\,m_2v_2^{\,2}$
√	$= \frac{1}{2}\,(4.0\text{ kg})(9.0\text{ m/s})^2 + \frac{1}{2}\,(2.0\text{ kg})(3.0\text{ m/s})^2$
√ √	$= 2\,(81)\text{ J} + 1\,(9.0)\text{ J}$
√ √	$= 171$ J

Scoring Scheme	Answer
✓	E_{k_T} (at minimum separation) $= \frac{1}{2}(m_1 + m_2)V^2$
✓	$= \frac{1}{2}(4.0\ \text{kg} + 2.0\ \text{kg})(7.0\ \text{m/s})^2$
	$= 3.0\ (49)\ \text{kg}\cdot\text{m}^2/\text{s}^2$
✓ ✓	$= 147\ \text{J}$
✓	$\Delta E_p = -\Delta E_k$
✓	$= -(147\ \text{J} - 171\ \text{J})$
✓ ✓	$= 24\ \text{J}$
✓	The potential energy stored at minimum separation is 24 J.

8 A cart having a mass of 4.0 kg is travelling at 9.0 m/s horizontally to the right. It collides with a 2.0 kg cart travelling at 3.0 m/s in the same direction. The collision is cushioned by a perfectly elastic bumper, and friction is negligible.

S17C
III.5.c

54
43

F1
A8

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Let X represent the velocity of the 4.0 kg cart after collision and Y represent the velocity of the 2.0 kg cart after collision. Using the given data, construct two equations in X and Y which can be used to find the final velocities. Do <u>not</u> solve these equations.

Scoring Scheme | Answer

Let (+) represent "to the right".

✓ $m_1 = 4.0$ kg $\qquad m_2 = 2.0$ kg

$\vec{v}_1 = +9.0$ m/s $\qquad \vec{v}_2 = +3.0$ m/s

$\vec{v}_1{}' = X \qquad \vec{v}_2{}' = Y$

✓ Momentum is conserved

✓ $\vec{p}_T = \vec{p}_T{}'$

✓ $m_1\vec{v}_1 + m_2\vec{v}_2 = m_1\vec{v}_1{}' + m_2\vec{v}_2{}'$

✓ $(4.0 \text{ kg})(9.0 \text{ m/s}) + (2.0 \text{ kg})(3.0 \text{ m/s}) = (4.0 \text{ kg})X + (2.0 \text{ kg})Y$

$36 + 6.0 = 4.0\ X + 2.0\ Y$

✓ $21 = 2.0\ X + 1.0\ Y$, for X and Y in m/s (1st eqn.)

✓ Since the collision is elastic, kinetic energy is conserved.

✓ $\frac{1}{2} m_1 v_1{}^2 + \frac{1}{2} m_2 v_2{}^2 = \frac{1}{2} m_1 (v_1{}')^2 + \frac{1}{2} m_2 (v_2{}')^2$

✓ $\frac{1}{2}(4.0 \text{ kg})(9.0 \text{ m/s})^2 + \frac{1}{2}(2.0 \text{ kg})(3.0 \text{ m/s})^2$

$= \frac{1}{2}(4.0 \text{ kg})X^2 + \frac{1}{2}(2.0 \text{ kg})Y^2$

✓ $171 = 2.0\ X^2 + 1.0\ Y^2$ for X and Y in m/s (2nd eqn.)

The two equations that can be used to find the final velocities are:

✓ $2.0\ X + 1.0\ Y = 21$

$2.0\ X^2 + 1.0\ Y^2 = 171$

9

S17C
III.5.c

54
43

F1
A8

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A cart having a mass of 4.0 kg is travelling at 9.0 m/s horizontally to the right. It collides with a 2.0 kg cart travelling at 3.0 m/s in the same direction. The collision is perfectly elastic and friction is negligible.

Determine the velocity of each cart after the collision.

Scoring Scheme — Answer

✓ Let (+) represent "to the right"

$m_1 = 4.0$ kg $\qquad m_2 = 2.0$ kg

✓ $\vec{v}_1 = +9.0$ m/s $\qquad \vec{v}_2 = +3.0$ m/s

$\vec{v}_1{}' = X \qquad \vec{v}_2{}' = Y$

(a) Momentum is conserved

✓ $\vec{p}_T = \vec{p}_T{}'$

✓ $m_1 \vec{v}_1 + m_2 \vec{v}_2 = m_1 \vec{v}_1{}' + m_2 \vec{v}_2{}'$

✓ $(4.0 \text{ kg})(9.0 \text{ m/s}) + (2.0 \text{ kg})(3.0 \text{ m/s}) = (4.0 \text{ kg})\ X + (2.0 \text{ kg})\ Y$

$36 + 6.0 = 4.0\ X + 2.0\ Y$

✓ $21 = 2.0\ X + 1.0\ Y$, for X and Y in m/s (1st eqn.)

Since the collision is elastic, kinetic energy is conserved.

✓ $\frac{1}{2} m_1 v_1{}^2 + \frac{1}{2} m_2 v_2{}^2 = \frac{1}{2} m_1 (v_1{}')^2 + \frac{1}{2} m_2 (v_2{}')^2$

✓ $\frac{1}{2}(4.0 \text{ kg})(9.0 \text{ m/s})^2 + \frac{1}{2}(2.0 \text{ kg})(3.0 \text{ m/s})^2 = \frac{1}{2}(4.0 \text{ kg})\ X^2 + \frac{1}{2}(2.0 \text{ kg})\ Y^2$

✓ $171 = 2.0\ X^2 + 1.0\ Y^2$, for X and Y in m/s (2nd eqn.)

Scoring Scheme	Answer
	The two equations that can be used to find the final velocities are:
	$2.0\ X + 1.0\ Y = 21$
	$2.0\ X^2 + 1.0\ Y^2 = 171$
	From the first equation,
✓	$Y = 21 - 2.0\ X$
	Substitute this into the second equation,
✓	$2.0\ X^2 + (21 - 2.0\ X)^2 = 171$
	$2.0\ X^2 + 441 - 84\ X + 4.0\ X^2 = 171$
✓	$6.0\ X^2 - 84\ X + 270 = 0$
✓	$1.0\ X^2 - 14\ X + 45 = 0$
✓ ✓	$(X - 5.0)\ (X - 9.0) = 0$
✓ ✓	$X = 5.0$ or $X = 9.0$
✓	Since $X = 9.0$ represents the initial condition,
✓	$X = 5.0$
✓	Substitute $X = 5.0$ into the first equation.
	$2.0\ (5.0) + 1.0\ Y = 21$
✓	$Y = 11$
✓ ✓ ✓ ✓	After the collision, the velocity of the 4 kg cart is 5.0 m/s to the right, and the velocity of the 2 kg cart is 11 m/s to the right.

10

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III.5.c

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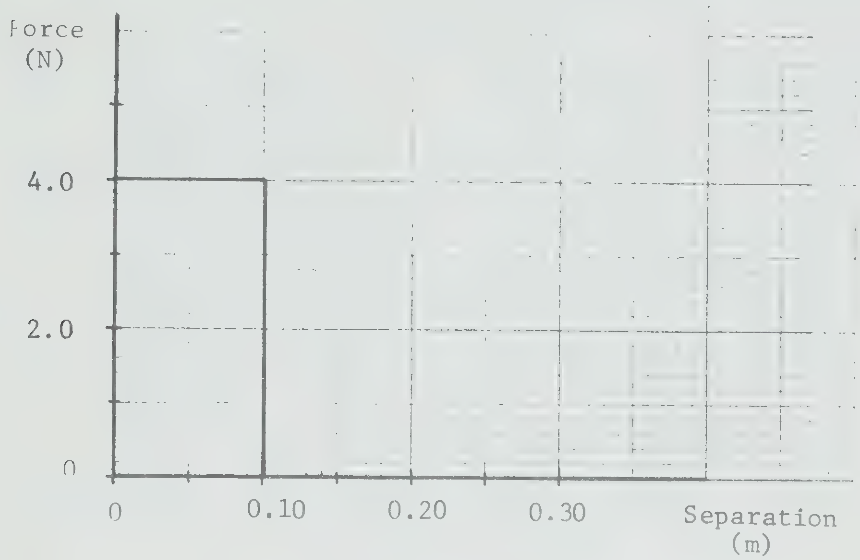
A 5.0 kg body is at rest. A 10 kg body approaches it with a velocity of 0.20 m/s. The repulsive force which acts during the collision between the two bodies is shown on the graph.



(a) Calculate the kinetic energy of each mass before the interaction.

(b) Calculate the velocity of each mass when the separation is at a minimum.

Scoring Scheme

Answer

Let (+) represent 'to the right'

✓ $m_a = 5.0$ kg $\quad v_a = 0$

$m_b = 10$ kg $\quad v_b = 0.20$ m/s

(a) $E_{k_a} = \frac{1}{2} m_a v_a^2$

$= \frac{1}{2}$ (5.0 kg) (0)

✓ $= 0$

Scoring Scheme	Answer
√	$E_{k_b} = \frac{1}{2}$ (10 kg) (0.20 m/s)^2
√	= 5.0 (0.040) J
√ √	= 0.20 J
√	The 5.0 kg mass has a kinetic energy of zero and the 10 kg mass has a kinetic energy of 0.20 J before the interaction.
√	(b) At minimum separation both masses have the same velocity.
√	Let v' represent the common velocity at minimum separation.
√	$\vec{p}_T = \vec{p}_T'$
√	$m_a \vec{v}_a + m_b \vec{v}_b = (m_a + m_b) \vec{v}'$
√	$0 + (10\ \text{kg})\ (0.20\ \text{m/s}) = (5.0\ \text{kg} + 10\ \text{kg})\ \vec{v}'$
	$2.0\ \text{kg·m/s} = (15\ \text{kg})\ \vec{v}'$
√ √	$v' = 0.13$ m/s
√	The velocity of each mass at minimum separation is 0.13 m/s.

11 A 5.0 kg body is at rest. A 10 kg body approaches it with a velocity of 0.20 m/s. The repulsive force which acts during the collision between the two bodies is shown on the graph. The velocity of each mass when the separation is at a minimum is 0.13 m/s.

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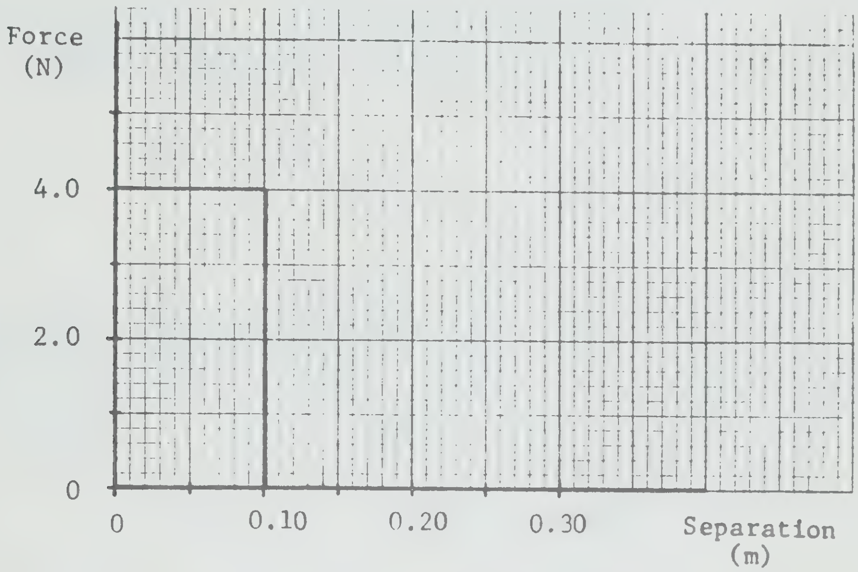

(a) Calculate how much kinetic energy 'disappears' from the system from the time when the collision starts until the time when the separation is at a minimum.

(b) What is the minimum separation?

Scoring Scheme

Answer

Let (+) represent 'to the right'.

√ $m_a = 5.0$ kg $\qquad v_a = 0$

$m_b = 10$ kg $\qquad v_b = 0.20$ m/s

Let v' represent the common velocity at minimum separation.

$v' = 0.13$ m/s

Scoring Scheme	Answer
	(a) Let $E_k{}'$ be the kinetic energy at minimum separation.
✓	$\Delta E_k = E_k{}' - E_k$
✓	$= \frac{1}{2}(m_a + m_b)v'^2 - \frac{1}{2}m_a v_a{}^2 - \frac{1}{2}m_b v_b{}^2$
✓	$= \frac{1}{2}(5.0\text{ kg} + 10\text{ kg})(0.13\text{ m/s})^2 - 0 - \frac{1}{2}(10\text{ kg})(0.20\text{ m/s}$
	$= 0.13\text{ J} - 0.200\text{ J}$
✓ ✓ ✓	$= -0.070\text{ J}$
✓ ✓	The amount of kinetic energy which "disappears" is 0.070 J.
✓	(b) Let the change in separation to minimum separation be Δs.
✓	$F = 4.0$ N, from the graph
✓	$\Delta E_k = 0.070\text{ J}$
✓	$F\Delta s = \Delta E_k$
✓	$\Delta s = \dfrac{\Delta E_k}{F}$
✓	$= \dfrac{0.070\text{ J}}{4.0\text{ N}}$
✓ ✓	$= 0.018\text{ m}$
✓	The separation at the start of the collision is 0.10 m.
	The minimum separation is
✓	0.10 m - 0.018 m
✓	= 0.082 m
✓	Minimum separation is 0.08 m.

GRAVITATIONAL POTENTIAL ENERGY

1 The equation for gravitational potential energy near the surface of the earth is $E_g = mgh$.

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I.3.b
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III.6.c

State the SI unit for each of the symbols in the equation.

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A2

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E_g ____________________

m ____________________

g ____________________

h ____________________

Scoring Scheme	Answer
✓	E_g is in J or N·m or $kg \cdot m^2/s^2$
✓	m is in kg
✓	g is in m/s^2 or N/kg
✓	h is in m

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S17A
I.3.b
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A squirrel gathers 600 nuts together on the ground before storing them in a tree. What is the minimum amount of work done by the squirrel in storing the nuts if the mass of each nut is 0.010 kg and the store house is 6.0 m above the ground? (g = 10 N/kg)

Scoring Scheme	Answer
√	m = 0.010 kg/nut h = 6.0 m N = 600 nuts g = 10 N/kg
	Mass of nuts moved = number of nuts x mass of each nut
	$m_t = mN$
√	= 0.010 kg/nut x 600 nuts
√	= 6.0 kg
√	Work done = gain in gravitational potential energy
√	$E_g = m_t gh$
√	= 6.0 kg x 10 N/kg x 6.0 m
	= 360 N·m
	= 360 J
√ √	= 3.6×10^2 J
√	The squirrel does 3.6×10^2 J of work. (This neglects the work done in moving the squirrel.)

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S17A
I.3.d
S17C
III.6.c

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A 60 kg physics teacher climbs a staircase 6.0 m high in a time of 5.0 s. (g = 10 N/kg)

(a) Compute the increase in the gravitational potential energy of the teacher.

(b) What minimum power was required for the climb?

Scoring Scheme | Answer

✓ m = 60 kg g = 10 N/kg

h = 6.0 m t = 5.0 s

✓ (a) $\Delta E_g = mg\Delta h$

✓ $= 60\text{ kg} \times 10\text{ N/kg} \times 6.0\text{ m}$

$= 3600\text{ N}\cdot\text{m}$

$= 3600\text{ J}$

✓ ✓ $= 3.6 \times 10^3\text{ J}$

✓ The increase in gravitational potential energy is 3.6×10^3 J.

✓ (b) $P = \frac{\Delta E_g}{t}$

✓ $= \frac{3.6 \times 10^2\text{ J}}{5.0\text{ s}}$

$= 0.72 \times 10^2\text{ J/s}$

$= 0.72 \times 10^2\text{ W}$

✓ ✓ $= 7.2 \times 10^1\text{ W}$

✓ The minimum power was 7.2×10^1 W.

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S17C
III.6.c

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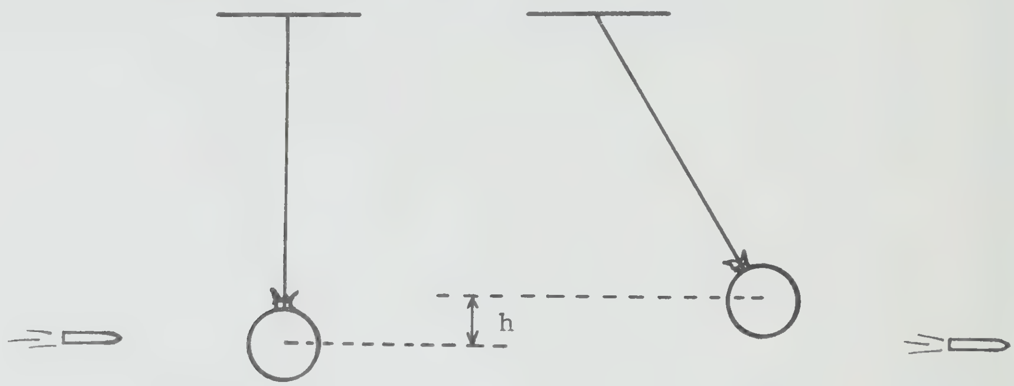
A 5.0 kg sandbag is suspended by a light cord as shown in the diagram. A 30 g bullet, travelling with a horizontal velocity of 300 m/s, penetrates the sandbag and leaves with a horizontal velocity of 100 m/s. The collision is inelastic.



before after

What is the speed of the sandbag immediately after the interaction with the bullet?

Scoring Scheme	Answer	
	M = mass of sandbag	$\vec{V}$ = horizontal velocity of sandbag
	= 5.0 kg	$\vec{v}$ = horizontal velocity of bullet before interaction
	m = mass of bullet	= 300 m/s
✓	= 30 g	
	= 0.030 kg	$\vec{v}'$ = horizontal velocity of bullet after interaction
		= 100 m/s

✓ $\vec{p}_T = \vec{p}_T{}'$

✓ $M\vec{V} + m\vec{v} = M\vec{V}' + m\vec{v}'$

✓ $(5.0\ \text{kg})\ (0) + (0.030\ \text{kg})\ (300\ \text{m/s}) = (5.0\ \text{kg})\ \vec{V}' + (0.030\ \text{kg})\ (100\ \text{m/}$

✓ ✓ $9.0\ \text{kg}\cdot\text{m/s} = (5.0\ \text{kg})\ \vec{V}' + 3.0\ \text{kg}\cdot\text{m/s}$

✓ ✓ $\vec{V}' = 1.2\ \text{m/s}$

✓ The speed of the sandbag just after the interaction with the bullet is 1.2 m/s.

5

S17C
III.6.c

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43

F1
A8

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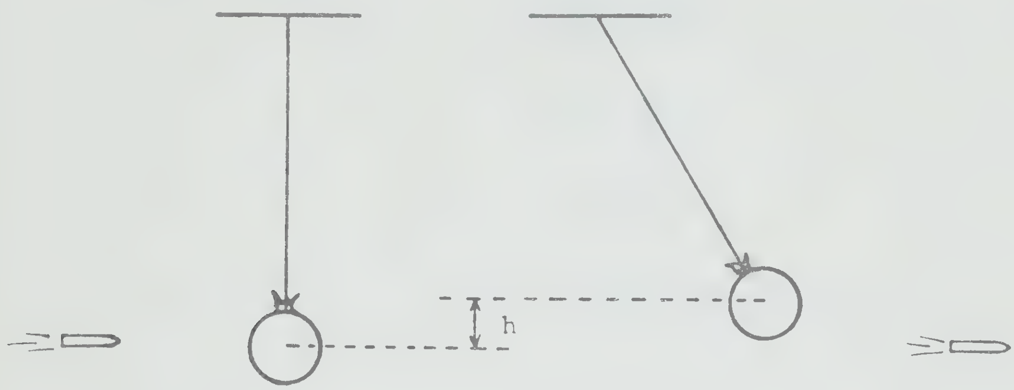
A 5.0 kg sandbag is suspended by a light cord as shown in the diagram. A 30 g bullet, travelling with a horizontal velocity of 300 m/s, penetrates the sandbag and leaves with a horizontal velocity of 100 m/s. The collision is inelastic. The speed of the sandbag after the interaction with the bullet is 1.2 m/s. (g = 10 m/s^2)



before after

Through what height h, in cm, does the sandbag rise? (Disregard air resistance.)

Scoring Scheme

Answer

M = mass of sandbag

= 5.0 kg

m = mass of bullet

✓ = 30 g

= 0.030 kg

$\vec{v}$ = horizontal velocity of bullet before interaction

= 300 m/s

$\vec{v}'$ = horizontal velocity of bullet after interaction

= 100 m/s

$\vec{V}'$ = horizontal velocity of sandbag after interaction

= 1.2 m/s

The kinetic energy of the sandbag is transformed to potential energy as the sandbag rises.

✓ $\Delta E_g = -\Delta E_k$

Scoring Scheme	Answer
✓ ✓	$Mgh - 0 = -(0 - \frac{1}{2}MV^2)$
✓	$h = \dfrac{V^2}{2g}$
✓	$= \dfrac{(1.2 \text{ m/s})^2}{2\ (10 \text{ m/s}^2)}$
	$= \dfrac{1.44}{20}$ m
	$= 0.072$ m
✓ ✓	$= 7.2$ cm
✓	The sandbag rises 7.2 cm.

6

An albatross of mass 8.0 kg is flying 60 m above the earth at a speed of 10 m/s. (g = 10 N/kg)

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I.3.b
S17C
III.6.c

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(a) Determine the kinetic energy of the albatross.

(b) Determine the gravitational potential energy of the albatross relative to the surface of the earth.

Scoring Scheme	Answer	
√	m = 8.0 kg	v = 10 m/s
	h = 60 m	g = 10 N/kg
√	(a) $E_k = \frac{1}{2} mv^2$	
√	$= \frac{1}{2} \times 8.0 \text{ kg} \times (10 \text{ m/s})^2$	
√ √	$= 400 \text{ kg·m}^2/\text{s}^2$	
	$= 400$ J	
√ √	$= 4.0 \times 10^2$ J	
√	The kinetic energy of the albatross is 4.0×10^2 J.	
√	(b) $E_g = mgh$	
√	= (8.0 kg) (10 N/kg) (60 m)	
	= 4800 N·m	
	= 4800 J	
√ √	$= 4.8 \times 10^3$ J	
√	The gravitational potential energy of the albatross is 4.8×10^3 J.	

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S17C
III.6.c

S 55
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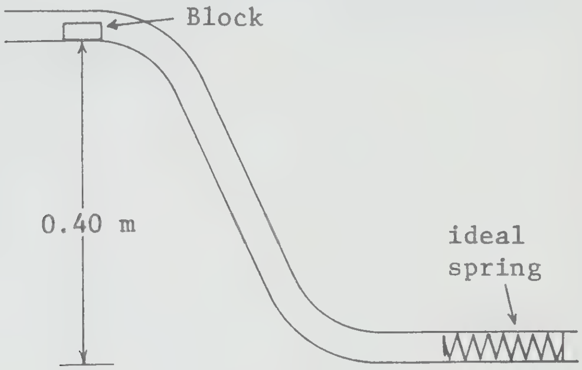
A block having a mass of 8.0 kg slides down a frictionless tube from a height of 0.40 m. At the bottom it travels horizontally and compresses an ideal spring 8.0 cm. Determine the spring constant k. (g = 10 N/kg)



Scoring Scheme	Answer	
	m = 8.0 kg	x = compression of spring
√	h = 0.40 m	= 8.0 cm
√		= 0.080 m

√ Since the total mechanical energy is conserved, the gravitational potential energy of the block before the slide is transferred to the elastic potential energy stored in the spring at maximum compression.

√ ΔE_{s} (spring) $= -\Delta E_{g}$ (gravity)

√ $\frac{1}{2} kx^2 - 0 = -(0 - mgh)$

√ $k = \frac{2\ mgh}{x^2}$

√ $= \frac{2\ (8.0\ kg)\ (10\ N/kg)\ (0.40\ m)}{(0.080\ m^2)}$

√ √ $= 1.0 \times 10^4$ N/m

√ The spring constant is 1.0×10^4 N/m

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S17C
III.6.c

S 55
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A spring suspended at rest is shown in diagram I.

Diagram II shows a 1.0 kg mass hanging at rest from the same spring and causing an extension *d*.

The mass is then pulled down an additional distance of 10 cm as shown in diagram III.

The spring constant is 50 N/m and g = 10 N/kg.

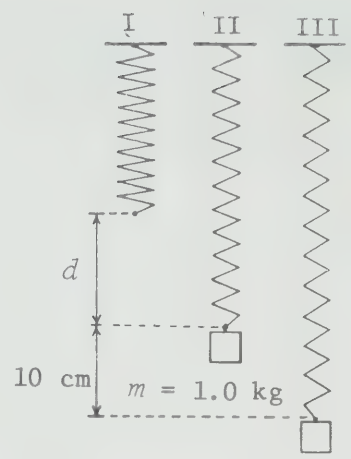

Diagram not drawn to scale.

(a) Determine the extension *d*.

(b) Calculate the amount of work required to extend the spring from the position shown in diagram I, to that shown in diagram III.

Scoring Scheme | Answer

(a) m = 1.0 kg $\qquad g$ = 10 N/kg

✓ $F = kx$

✓ $F = mg$

✓ $mg = kx$

✓ (1.0 kg)(10 N/kg) = (50 N/m) d

✓ $d = \dfrac{10\text{ N}}{50\text{ N/m}}$

✓ ✓ $= 0.20$ m

✓ The extension is 0.20 m under the influence of the force of gravity on the mass.

Scoring Scheme	Answer
✓	(b) $x_{I} = 0$
✓	$x_{III} = 0.20\ \text{m} + 0.10\ \text{m}$
✓	$W = \Delta E_s$
✓	$= \frac{1}{2}\ k\ x_{III}^{\ 2} - \frac{1}{2}\ k\ x_{I}^{\ 2}$
✓	$= \frac{1}{2}\ (50\ \text{N/m})\ (0.20\ \text{m} + 0.10\ \text{m})^2 - 0$
	$= 25\ (0.30)^2\ \text{N}\cdot\text{m}$
✓	$= 25\ (0.09)\ \text{N}\cdot\text{m}$
	$= 2.25\ \text{J}$
✓ ✓	$= 2.3\ \text{J}$
✓	The work required to extend the spring from position I to position III is 2.3 J.

9

S17C
III.6.a

SS 55

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The equation for the force $\vec{F}$ exerted by a spring which is compressed through a displacement $\vec{x}$ is $\vec{F} = -k\vec{x}$, where k is the spring constant.

(a) Solve the equation for k.

(b) Solve the equation for $\vec{x}$.

Scoring Scheme	Answer
√	(a) $k = \frac{-F}{x}$
√	(b) $\vec{x} = \frac{-\vec{F}}{k}$

10	A light cord passes over a light frictionless pulley as shown. A 5.0 kg mass hangs from one end of the cord and a 3.0 kg mass hangs from the other end. The system is initially at rest.	
S17C		
III.6.c		
56		
A8	Determine the speed of each mass when the 5.0 kg mass has fallen 0.80 m from its rest position by using the principle of conservation of energy. (g = 10 N/kg)	
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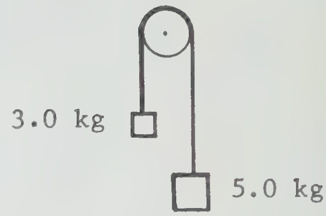

NOTE: Other methods of determining the speed will not be accepted.

Scoring Scheme	Answer
	Let (+) represent "upward".
✓	$m_1 = 5.0$ kg $\quad \Delta h_1 = -0.80$ m
✓	$m_2 = 3.0$ kg $\quad \Delta h_2 = +0.80$ m, since the cord does not stretch
✓	$\Delta E_{g_1} = m_1 g \Delta h_1$
✓	$= (5.0\text{ kg})(10\text{ m/s}^2)(-0.80\text{ m})$
✓ ✓ ✓	$= -40$ J
✓	$\Delta E_{g_2} = m_2 g \Delta h_2$
✓	$= (3.0\text{ kg})(10\text{ m/s}^2)(+0.80\text{ m})$
✓ ✓	$= 24$ J
✓	$\Delta E_T = \Delta E_{g_1} + \Delta E_{g_2}$
✓	$= -40\text{ J} + 24\text{ J}$
✓	$= -16$ J
✓	$\Delta E_{K_T} = -\Delta E_T$
✓	$= 16$ J

Scoring Scheme	Answer
√	$(E_{K_T})_f = (E_{K_T})_i + \Delta E_{K_T}$
√	$\frac{1}{2}\,(m_1 + m_2)\,v_f^{\,2} = 0 + \Delta E_{K_T}$
√	$v_f^{\,2} = \dfrac{2(\Delta E_{K_T})}{m_1 + m_2}$
√	$= \dfrac{2\ (16\ \text{J})}{5.0\ \text{kg} + 3.0\ \text{kg}}$
√	$= 4\ \text{m}^2/\text{s}^2$
√ √	$v_f = 2\ \text{m/s}$
√ √	The speed of each mass is 2 m/s when the 5.0 kg mass has fallen 0.80 m.

11

S17C
III.6.c

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S 55

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A spring suspended at rest is shown in diagram I.

Diagram II shows a 1.0 kg mass hanging at rest from the same spring and causing an extension of 20 cm.

To extend the spring from position I to position III, as shown in the diagram, requires 2.25 J of work.

The spring constant is 50 N/m and g = 10 N/kg.

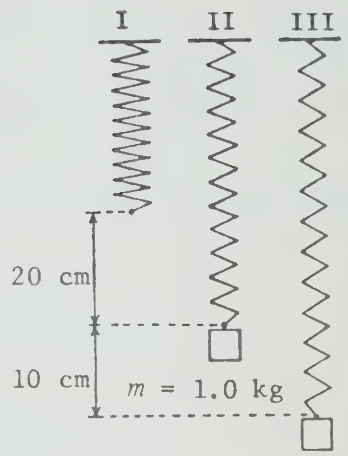

Diagram not drawn to scale

(a) If the mass is released from the position shown in diagram III, what will be the extension of the spring when the mass reaches its maximum speed?

(b) Calculate the maximum speed of the mass.

Scoring Scheme

Answer

m = 1.0 kg g = 10 N/kg

✓ w = work to extend from x = 0 to x = 0.30 m

= 2.25 J

✓ (a) The maximum speed occurs at the midpoint of the oscillation (since potential energy is minimum here).

✓ The mass oscillates between x = 0.30 m and x = 0.10 m.

✓ ✓ ∴ when the speed is at maximum, the extension of the spring will be 0.20 m.

(b) The total mechanical energy is conserved.

✓ $E_T = E_s$ (at 0.30 m extension)

✓ = 2.25 J

✓ $E_T = E_k + E_s$ (spring) + E_g (gravity)

✓ $= \frac{1}{2} mv^2 + \frac{1}{2} kx^2 + mg\Delta h$

Scoring Scheme	Answer
√	The maximum speed will occur at an extension of 0.20 m.
√	$\frac{1}{2}$ (1.0 kg) v^2 + $\frac{1}{2}$ (50 N/m) $(0.20\ \text{m})^2$
√	+ (1.0 kg) (10 N/kg) (0.10 m)
√	= 2.25 J
	(0.5 kg) v^2 + 1.0 J + 1.0 J = 2.25 J
	$v^2 = 0.50\ \text{m}^2/\text{s}^2$
√ √	$v = 0.71$ m/s
√	The maximum speed is 0.71 m/s.

12

S17C
III.6.d

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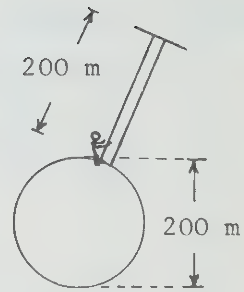
Suppose someone has built a tower of negligible mass on a tiny round asteroid. There is a platform at the top of the tower and the platform is 200 m above the asteroid's surface. The asteroid has a diameter of 200 m and a mass of 1.4×10^{10} kg. ($G = 6.7 \times 10^{-11}$ N·m²/kg²)



How much work would a 60 kg person do in climbing from the surface of the asteroid to the platform? (Express the answer in joules correct to one significant figure.)

Scoring Scheme	Answer
	h = 200 m, height of platform above surface
	r = 100 m, radius of asteroid
✓	$M = 1.4 \times 10^{10}$ kg, mass of asteroid
	m = 60 kg, mass of person
	$G = 6.7 \times 10^{-11}$ N·m²/kg²
	The amount of work the person must do in the climbing is equal to the change in potential energy from the surface of the asteroid to the platform.
✓	$W = E_{g \text{ on platform}} - E_{g \text{ on surface}}$
✓	$E_{g \text{ on surface}} = \dfrac{-GMm}{r}$
✓	$= \dfrac{-(6.7 \times 10^{-11}\ \text{N·m}^2/\text{kg}^2)(1.4 \times 10^{10}\ \text{kg})(60\ \text{kg})}{100\ \text{m}}$
✓ ✓	$= -0.563$ J
✓	$E_{g \text{ on platform}} = \dfrac{-GMm}{r + h}$
✓	$= \dfrac{-6.7 \times 10^{-11}\ \text{N·m}^2/\text{kg}^2)(1.4 \times 10^{10}\ \text{kg})(60\ \text{kg})}{100\ \text{m} + 200\ \text{m}}$
✓ ✓	$= -0.188$ J

Scoring Scheme	Answer
√ √	$W = (-0.188\ \text{J}) - (-0.563\ \text{J})$
	$= 0.375\ \text{J}$
√ √	$= 0.40\ \text{J}$
√	The work done in the climb is 0.40 J.

13

S17C
III.6.e

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Assume that a space capsule having a mass of 900 kg is projected vertically upward from the earth's surface with an initial kinetic energy of 7.00×10^9 J. The mass of the earth is 5.98×10^{24} kg, the radius of the earth is 6.38×10^6 m, and the gravitational constant is 6.67×10^{-11} N·m²/kg².

Assuming air resistance is negligible, determine the maximum distance from the centre of the earth attained by the capsule.

Scoring Scheme | Answer

M = mass of earth = 5.98×10^{24} kg

r_i = radius of earth = 6.38×10^6 m

✓ $G = 6.67 \times 10^{-11}$ N·m²/kg²

m = mass of capsule = 9.00×10^2 kg

$E_{k_i} = 7.00 \times 10^9$ J

✓ At maximum height, the kinetic energy of the capsule will be zero.

✓ $E_f = E_i$, since air resistance is negligible.

Method A

✓ $-\Delta E_k = \Delta E_g$

✓ $-(E_{k_f} - E_{k_i}) = E_{g_f} - E_{g_i}$

✓ $-(0 - E_{k_i}) = \frac{-GMm}{r_f} - (-\frac{GMm}{r_i})$

✓ $E_{k_i} = GMm\,(\frac{1}{r_i} - \frac{1}{r_f})$

Scoring Scheme	Answer
✓	$7.00 \times 10^9 \text{ J} = (6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24} \text{ kg})$
	$\times (9.00 \times 10^2 \text{ kg})\left(\frac{1}{6.38 \times 10^6 \text{ m}} - \frac{1}{r_f}\right)$
✓	$7.00 \times 10^9 = (6.67)(5.98)(9)(10^{-11})(10^{24})(10^2)$
	$\times \left(\frac{1 \times 10^{-6}}{6.38} - \frac{1}{r_f}\right)$
	for r_f in m
✓	$7.00 \times 10^9 = (3.598 \times 10^{17})\left(1.567 \times 10^{-7} - \frac{1}{r_f}\right)$
✓	$\frac{1}{r_f} = 1.567 \times 10^{-7} - \frac{7.00 \times 10^9}{3.598 \times 10^{17}}$
✓ ✓	$= 1.567 \times 10^{-7} - 1.95 \times 10^{-8}$
✓	$= 1.372 \times 10^{-7}$
	$r_f = 0.7288 \times 10^7$
	$= 7.288 \times 10^6$
✓ ✓ ✓	$= 7.29 \times 10^6$ m
✓	The maximum distance from the centre of the earth attained by the capsule is 7.3×10^6 m.
	Method B
	At the Surface of the Earth
	$E_k = 7.00 \times 10^9$ J
✓	$E_p = \frac{-GMm}{r_i}$
✓	$= (-6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24} \text{ kg})(9.00 \times 10^2 \text{ kg})$
	$\left(\frac{1}{6.38 \times 10^6 \text{ m}}\right)$
✓ ✓	$= -5.63 \times 10^{10}$ J

Scoring Scheme	Answer
√	$E_T = E_k + E_p$
	$= 7.00 \times 10^9\ J + (-5.63 \times 10^{10}\ J)$
√ √	$= -4.93 \times 10^{10}\ J$
	<u>At Maximum Height</u>
√	$E_k = 0$
√	$\therefore E_p = -4.93 \times 10^{10}\ J$
√	$= \frac{-GMm}{r_f}$
√	$= (-6.67 \times 10^{-10}\ N{\cdot}m^2/kg^2)\ (5.98 \times 10^{24}\ kg)$
	$(9.00 \times 10^2\ kg)\ (\frac{1}{f})$
√ √ √	$r_f = 7.28 \times 10^6\ m$
√	The maximum distance from the centre of the earth attained by the capsule is 7.3×10^6 m.

14 Column I below lists a number of physical quantities. Column II lists a number of SI units.

S17A
I.3.d
S17C
III.6.f

In the space provided before each quantity in Column I, write the letter corresponding to the appropriate SI unit from Column II. A particular unit from Column II may be used once, more than once, or not at all.

S 57
4

A2
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Answer & Scoring Scheme			I Physical Quantity		II SI Unit
√ (B)	______	1.	acceleration	(A)	m/s
√ (I)	______	2.	coefficient of friction	(B)	m/s^2
√ (G)	______	3.	energy	(C)	m^2/s^2
√ (E)	______	4.	force	(D)	kg·m/s
√ (G)	______	5.	heat	(E)	$kg \cdot m/s^2$
√ (H)	______	6.	power	(F)	$kg \cdot m^2/s$
√ (A)	______	7.	speed	(G)	$kg \cdot m^2/s^2$
√ (G)	______	8.	work	(H)	$kg \cdot m^2/s^3$
				(I)	no unit

15

S17C
III.6.e

S 57

F1
A8

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A rocket of mass m is at rest on a launch pad on the surface of a planet of mass M and radius r. P is a point at infinite separation from the planet. At P a mass would have a gravitational potential energy of zero

(a) Write the equation that expresses the gravitational potential energy of the rocket with respect to P.

(b) Assume that the rocket leaves the launch pad with a speed v. Write the equation that expresses the total mechanical energy of the rocket in terms of some or all of m, M, r, G and v.

(c) Derive the equation which expresses the escape velocity v_e of the rocket in terms of some or all of m, M, r and G.

(d) If the mass of the rocket were doubled, what would be the effect on its escape velocity? Explain your answer.

Scoring Scheme	Answer
✓	(a) $E_g = \frac{-GMm}{r}$
✓ ✓ ✓	(b) $E_T = \frac{1}{2} mv^2 - \frac{GMm}{r}$
✓ ✓ ✓	(c) If the satellite "just escapes", its final velocity will be zero, and therefore its final kinetic energy will be zero; also the separation between the two masses will approach infinity and therefore the final potential energy will approach zero.
✓	$E_{final} = 0$ in order to "just escape".
✓	$E_{initial} = \frac{1}{2} m v_e^2 - \frac{GMm}{r}$
✓	$\frac{1}{2} m v_e^2 - \frac{GMm}{r} = 0$
✓	$v_e^2 = \frac{2GM}{r}$
✓	$v_e = \sqrt{\frac{2GM}{r}}$
✓ ✓	(d) Since v_e is independent of m, doubling the mass of the satellite has no effect on its escape velocity.

16

S17C
III.6.e

S 57
56
53

F1

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Assume that a space capsule having a mass of 900 kg is projected vertically upward from the earth's surface. The mass of the earth is 5.98×10^{24} kg, the radius of the earth is 6.38×10^{6} m, and the gravitational constant is $6.67 \times 10^{-11}\ \mathrm{N{\cdot}m^2/kg^2}$.

Neglecting air resistance, determine the initial speed that the capsule will need in order to "just escape".

Scoring Scheme | Answer

A. If students have not been taught $v_e = \sqrt{\frac{2GM}{r}}$

M = mass of earth = 5.98×10^{24} kg

✓ r = radius of earth = 6.38×10^{6} m

$G = 6.67 \times 10^{-11}\ \mathrm{N{\cdot}m^2/kg^2}$

m = mass of capsule = 9.00×10^{2} kg

✓ In order to "just escape", the final kinetic energy of the capsule must be zero.

✓ The distance from the capsule to the earth must approach infinity, therefore the final potential energy approaches zero.

✓ $E_f = E_i$, since air resistance is negligible

Method I

✓ $-\Delta E_k = \Delta E_g$

✓ $-(E_{k_f} - E_{k_i}) = E_{g_f} - E_{g_i}$

$-(0 - E_{k_i}) = 0 - (-\frac{GMm}{r})$

✓ $E_{k_i} = \frac{GMm}{r}$

Scoring Scheme	Answer
✓	$E_{k_i} = \dfrac{(6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg})(9.00 \times 10^2\ \text{kg})}{(6.38 \times 10^6\ \text{m})}$
	$= \dfrac{(6.67)\ (5.98)\ (9)\ (10^{-11})\ (10^{24})\ (10^2)}{6.38 \times 10^6}\ \text{J}$
	$= \dfrac{3.589 \times 10^{17}}{6.38 \times 10^6}\ \text{J}$
✓ ✓	$= 5.625 \times 10^{10}\ \text{J}$
✓	$\frac{1}{2} m v_e^{\ 2} = E_{k_i}$
✓	$v_e = \sqrt{\dfrac{2E_{k_i}}{m}}$
✓	$= \sqrt{\dfrac{2\ (5.625 \times 10^{10}\ \text{J})}{9.00 \times 10^2\ \text{kg}}}$
	$= \dfrac{10^4}{3} \sqrt{2\ (5.625)}\ \text{m/s}$
	$= \dfrac{10^4}{3} (3.354)\ \text{m/s}$
	$= 1.119 \times 10^4\ \text{m/s}$
✓ ✓	$= 1.12 \times 10^4$ m/s <u>or</u> 11.2 km/s
✓	The initial speed required is 11.2 km/s.
	<u>Method II</u>
	<u>At the Surface of the Earth</u>
✓	$E_k = \frac{1}{2} m v^2$
✓	$= \frac{1}{2}\ (900\ \text{kg})\ v^2$
✓	$E_p = \dfrac{-GMm}{r}$
✓	$= (-6.67 \times 10^{-11}\ \text{N}\cdot\text{m}^2/\text{kg}^2)(5.98 \times 10^{24}\ \text{kg})$
	$(9.00 \times 10^2\ \text{kg})\left(\dfrac{1}{6.38 \times 10^6\ \text{m}}\right)$

Scoring Scheme	Answer
✓	$E_T = E_k + E_p$
✓	$= \frac{1}{2}\,(900\ \text{kg})v^2 + (-6.67 \times 10^{-11}\ \text{N·m}^2/\text{kg}^2)$ $(5.98 \times 10^{24}\ \text{kg})\ (9.00 \times 10^2\ \text{kg})\ (\frac{1}{6.38 \times 10^6\ \text{m}})$
	<u>At Escape Distance</u>
✓	$E_T = 0$
	$E_T = E_k + E_p$
✓	$0 = \frac{1}{2}\,(900\ \text{kg})v^2 + (-6.67 \times 10^{-11}\ \text{N·m}^2/\text{kg}^2)$ $(5.98 \times 10^{24}\ \text{kg})\ (9.00 \times 10^2\ \text{kg})\ (\frac{1}{6.38 \times 10^6\ \text{m}})$
✓	$v^2 = 2\ (6.67 \times 10^{-11}\ \text{N·m}^2/\text{kg}^2)\ (5.98 \times 10^{24}\ \text{kg})$ $(9.00 \times 10^2\ \text{kg})\ (\frac{1}{(6.38 \times 10^6\ \text{m})\ (9.00 \times 10^2\ \text{kg})})$
	$= 1.250 \times 10^8\ \text{m}^2/\text{s}^2$
	$v = 1.119 \times 10^4\ \text{m/s}$
✓ ✓	$= 1.12 \times 10^4$ m/s or 11.2 km/s
✓	The initial speed required is 11.2 km/s.
	B. <u>If students have been taught $v_e = \sqrt{\frac{2GM}{r}}$</u>
	M = mass of earth = 5.98×10^{24} kg
	r = radius of earth = 6.38×10^6 m
	$G = 6.67 \times 10^{-11}\ \text{N·m}^2/\text{kg}^2$
	m - can be ignored
✓	$v_e = \sqrt{\frac{2GM}{r}}$
✓	$= \sqrt{\frac{2\ (6.67 \times 10^{-11}\ \text{N·m}^2/\text{kg}^2)\ (5.98 \times 10^{24}\ \text{kg})}{6.38 \times 10^6\ \text{m}}}$
✓ ✓	$= 1.12 \times 10^4\ \text{m/s}$
✓	The initial speed required is 1.12×10^4 m/s.

17 The equation for the energy E_s stored in a spring compressed through a displacement $\vec{x}$ is

S17C
III.6.a

$$E_s = \tfrac{1}{2}kx^2$$

SS 57 where k is the force constant of the spring.

A2 (a) State the SI derived unit with a compound name for k.

**
* (b) State the SI derived unit with a compound name expressed in terms of base units for k.
–

(c) State the SI derived unit with a special name for E_s.

(d) State the SI derived unit with a compound name expressed in terms of base units for E_s.

Scoring Scheme	Answer
✓	(a) J/m^2 or N/m
✓	(b) kg/s^2
✓	(c) J
✓	(d) $kg{\cdot}m^2/s^2$

18 State in words the meaning of the term "spring constant".

S17C
III.6.a

SS 57

A2

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Scoring Scheme	Answer
√	It is a property of the spring
√	that indicates how much force is required
√	to extend
√	or compress a spring
√	by a unit displacement

19

S17C
III.6.a

SS 57
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A2

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The equation for the potential energy stored in an extended spring is $E_s = \frac{1}{2}kx^2$.

State the SI unit of measurement for the quantity represented by each symbol in this equation.

E_s ____________________

k ____________________

x ____________________

Scoring Scheme

Answer

√ E_s is in J or N·m or $kg \cdot m^2/s^2$

√ k is in N/m or kg/s^2

√ x is in m

20

S17C
III.6.a

SS 57

A8
A2

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State the SI unit for each of the quantities represented by the symbols $\vec{F}$, k, $\vec{x}$, in the Hooke's Law equation $\vec{F} = -k\vec{x}$.

Scoring Scheme	Answer
√	$\vec{F}$ is in N or $kg{\cdot}m/s^2$
√	k is in N/m or kg/s^2
√	$\vec{x}$ is in m

21

S17C
III.6.a

SS 57

A8
A4

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The equation for the force $\vec{F}$ exerted by a spring that is compressed through a displacement $\vec{x}$ is $\vec{F} = -k\vec{x}$, where k is the spring constant.

(a) What is the direction of $\vec{x}$ relative to $\vec{F}$? Justify your answer.

(b) What is the SI unit for the spring constant?

Scoring Scheme	Answer
✓	(a) $\vec{x}$ is opposite in direction to $\vec{F}$.
✓	The negative sign in the equation is the convention for opposite direction. If the spring is compressed, the force acts to restore the spring to equilibrium.
✓	(b) $\frac{N}{m}$ or $\frac{kg}{s^2}$

22 Write the equation for Hooke's Law for a spring and state the quantity represented by each symbol.

S17A
III.6.a

SS 57

A8
A11

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Scoring Scheme	Answer
√	$\vec{F} = -k\vec{x}$
√	where $\vec{F}$ is the restoring force
√	$\vec{x}$ is the resulting displacement
√	and k is the proportionality constant (or spring constant)

23

S17C
III.6.a

SS 57

E3
F1

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Consider the following data for the restoring force $\vec{F}$ exerted by a spring extended through a displacement $\vec{x}$.

For what range of extensions does the spring obey Hooke's Law?

$\vec{x}$ (m)	$\vec{F}$ (N)
0.10	60
0.15	90
0.20	120
0.25	150
0.28	180
0.30	210

Scoring Scheme	Answer
✓ ✓	The spring obeys Hooke's Law for extensions of 0 to 0.25 m.

24

S17C
III.6.a

SS 57

E3
F1

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Consider the following data for the restoring force $\vec{F}$ exerted by a spring extended through a displacement $\vec{x}$.

For what range of forces does the spring obey Hooke's Law?

$\vec{x}$ (m)	$\vec{F}$ (N)
0.10	60
0.15	90
0.20	120
0.25	150
0.30	190
0.35	245

Scoring Scheme	Answer
√ √	The spring obeys Hooke's Law for forces of 0 to 150 N.

25

S17C
III.6.a

SS 57

F1
A8

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Calculate the energy stored in an ideal spring having a spring constant of 400 N/m when it is compressed 0.30 m.

Scoring Scheme	Answer	
√	k = 400 N/m	x = 0.30 m
√	$E_s = \frac{1}{2}\ kx^2$	
√	$= \frac{1}{2} \times 400\ \text{N/m} \times (0.30\ \text{m})^2$	
	$= 200\ \text{N/m} \times 0.09\ \text{m}^2$	
√ √	$= 18\ \text{N}\cdot\text{m}$	
√	$= 18\ \text{J}$	
√	The energy stored is 18 J.	

26

S17C
III.6.a

SS 57

F1
A8
A3

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For an ideal spring whose spring constant is 400 N/m calculate the distance through which the spring must be extended to store an energy of 0.50 J.

Scoring Scheme	Answer
✓	$k = 400 \text{ N/m}$ $\quad\quad E_s = 0.50 \text{ J}$
✓	$E_s = \frac{1}{2} kx^2$
✓	$x = \sqrt{\frac{2\,E_s}{k}}$
✓	$= \sqrt{\frac{2 \times 0.50 \text{ J}}{400 \text{ N/m}}}$
	$= \sqrt{\frac{1.0 \text{ N·m}}{400 \text{ N/m}}}$
	$= \sqrt{0.0025 \text{ m}^2}$
✓ ✓	$= 0.05 \text{ m}$
✓	The spring must be extended 0.05 m

27 If a force of 450 N <u>extends</u> a spring through 0.09 m, then the force constant of that spring is ________.

S17C
III.6.a

SS 57

F1
A8

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Scoring Scheme	Answer
✓ ✓ ✓	5×10^3 N/m *or* 5×10^3 kg/s^2

BEHAVIOURS OF LIGHT

AND

MODELS OF LIGHT

GEOMETRIC OPTICS

1 Parallel rays of light are incident on a plane mirror, as shown.

S17A
II.3.a
S17C
II.1.a

Carefully draw the corresponding reflected rays.

59

B1
A4
All

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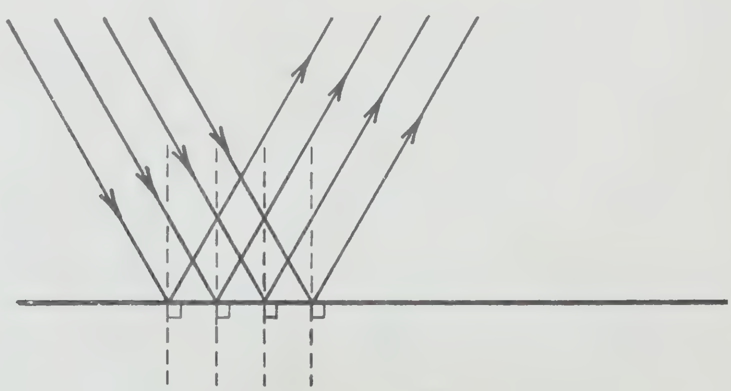
Scoring Scheme | Answer

✓ construction of normals ⊥ to surface

✓ $i = r$

✓ all rays parallel after reflection

✓ arrowheads shown



2

S17A
II.3.a

59

B1
A5
A8

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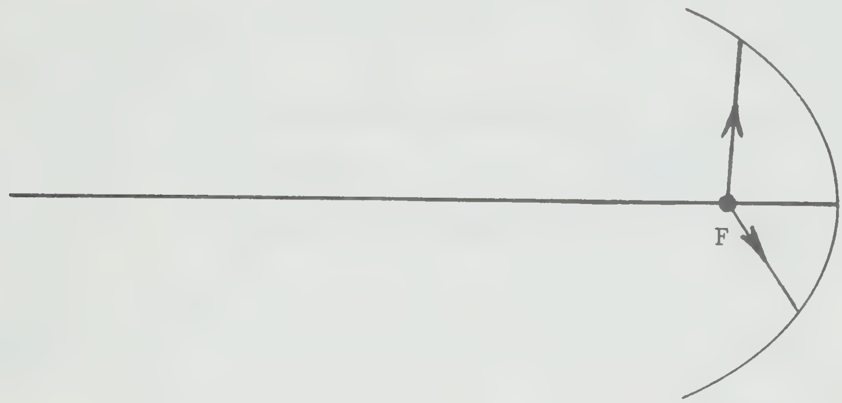
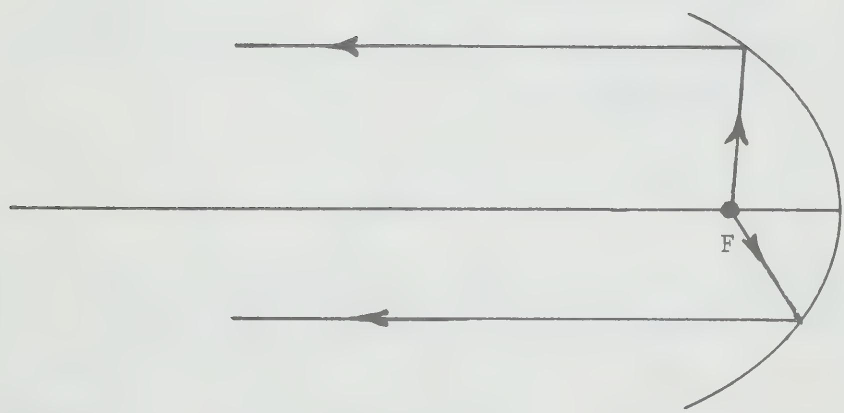
A light source is placed at the focus F of a parabolic mirror. Two rays are shown incident on the mirror.

Draw the path of both rays after they reflect from the mirror.



Scoring Scheme

Answer



✓ ✓ both rays parallel to principal axis after reflection

✓ ✓ arrowheads shown

(Some students may mistake the parabolic mirror for a spherical concave mirror and show spherical aberration.)

3

S17A
II.3.a
S17C
II.1.b

59

B1
A8
A11

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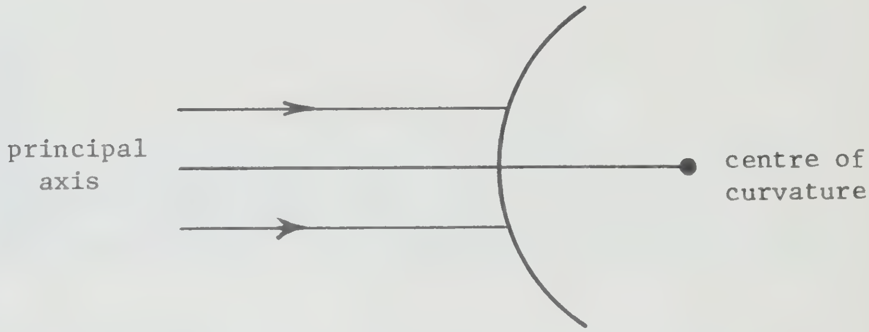
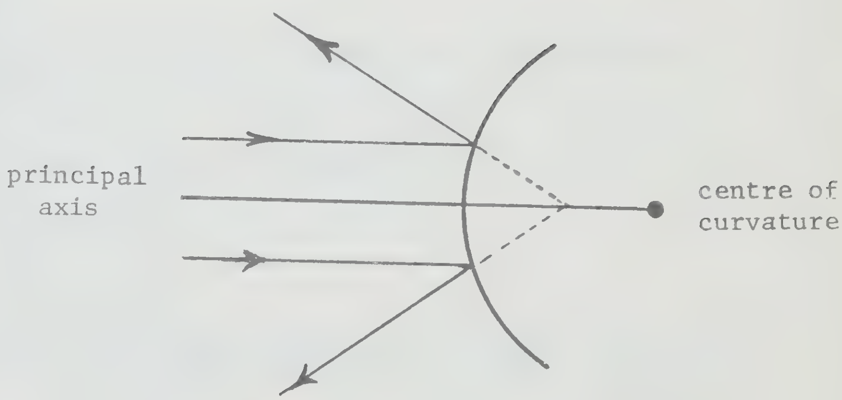
Two rays of light are shown travelling parallel to the principal axis of a convex spherical mirror.

Draw the corresponding reflected rays. Show clearly where the rays seem to come from after they leave the mirror.



Scoring Scheme	Answer
√	locating F
√ √	rays drawn from F
√ √	directions shown
√ √	dotted lines shown



4 Two rays of light are shown travelling parallel to the principal axis of a concave spherical mirror.

S17A
II.3.a Draw the corresponding reflected rays.

59

B1
A8
A5

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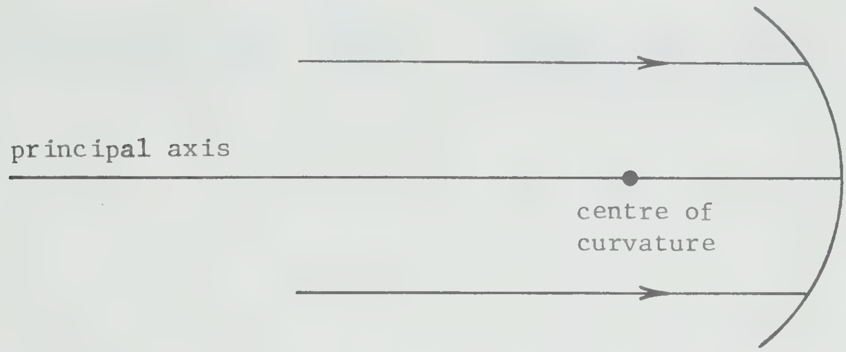
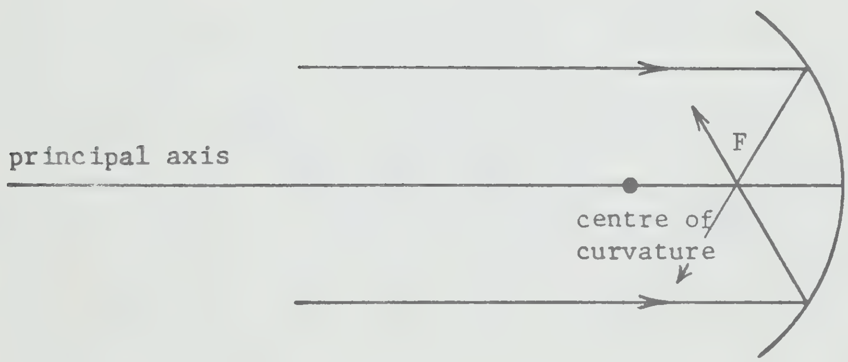


Scoring Scheme

Answer



Note: A similar diagram, but with one parallel ray further from the principal axis than the other can be used to evaluate spherical aberration.

√ location of F

√ √ both rays reflecting through F

√ √ arrowheads shown

CHARACTERISTICS AND BEHAVIOURS OF WAVES

1 On the diagram below place a point Y one wavelength to the right of point X.

S17A
II.1.b
S17C
II.3.a

69

A2

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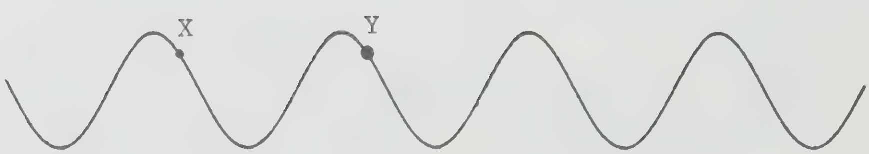
Scoring Scheme | Answer

√



2 A wave in which the particles of the medium vibrate parallel to the direction of wave travel is called a ________________ wave.

S17A
II.1.b

69

A2

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Scoring Scheme	Answer
√	longitudinal

3 A wave in which the particles of the medium vibrate at right angles to the direction of wave travel is called a ____________ wave.

S17A
II.1.b
S17C
II.3.a

69

A2

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Scoring Scheme	Answer
√	transverse

4

S17A
II.1.c
S17C
II.4.b

69
70

A2

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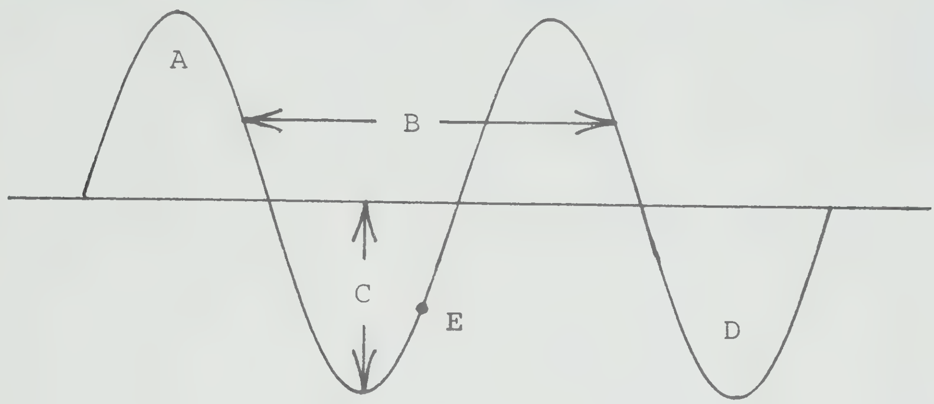
A cross section of a wave is shown below.



(a) Name the parts of the wave indicated by the letters A, B, C and D on the diagram.

A ____________________

B ____________________

C ____________________

D ____________________

(b) On the diagram, mark a point F that is in phase with the point E.

(c) Calculate the frequency of the wave if it makes 10 vibrations in 2 s.

Scoring Scheme	Answer
✓ ✓ ✓ ✓	(a) A. crest B. wavelength C. amplitude D. trough
✓	(b) The point on the wave which is one wavelength to the right of E.
✓	(c) Frequency is the number of complete vibrations per unit time.
✓ ✓	$\frac{10 \text{ vibrations}}{2 \text{ s}} = 5 \text{ Hz}$
✓	The frequency of the wave is 5 Hz.

5 State the quantity represented by each symbol in the equation $v = f\lambda$.

S17A
II.1.a
S17C
II.4.b

70

A2

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v ______________________

f ______________________

λ ______________________

Scoring Scheme	Answer
✓	v is the speed of the wave
✓	f is the frequency of the wave
✓	λ is the wavelength of the wave

6 The frequency of waves in a ripple tank is 6.0 Hz. What is the period of the waves?

S17A
II.1.a
S17C
II.4.b

70

F1
A3

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Scoring Scheme	Answer
	$f = 6.0$ Hz
✓	$T = \frac{1}{f}$
✓	$= \frac{1}{6.0 \text{ Hz}}$
✓ ✓	$= 0.17$ s
✓	The period of the waves is 0.17 s.

7 The period of vibration of a pendulum is 0.2 s. What is its frequency?

S17A
II.1.a
S17C
II.4.b

70

F1
A3

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Scoring Scheme	Answer
	$T = 0.2\ \text{s}$
✓	$f = \dfrac{1}{T}$
✓	$= \dfrac{1}{0.2\ \text{s}}$
✓ ✓	$= 5\ \text{Hz}$
✓	The frequency of the pendulum is 5 Hz.

8

S17A
II.1.c
S17C
II.4.b

70

F1
A8
A2

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During a storm large waves are created on a lake. The distance between successive wave crests is 2 m and the frequency of the waves is 0.4 Hz.

Calculate the speed of the waves.

Scoring Scheme	Answer	
✓	$\lambda = 2$ m	$f = 0.4$ Hz
✓	$v = f\lambda$	
✓	$= 0.4$ Hz x 2 m	
✓ ✓	$= 0.8$ m/s	
✓	The speed of the waves is 0.8 m/s.	

WAVE MODEL OF LIGHT AND INTERFERENCE

1

S17C
II.6.e

88
68

A9

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Enumerate the successes and failures of the particle and wave models in accounting for the behaviour of light as follows:

(a) Name five optical phenomena that are adequately accounted for by <u>both</u> models.

(b) Name four phenomena that are <u>not</u> adequately accounted for by the particle model.

(c) Name one phenomenon that is <u>not</u> adequately accounted for by the wave model.

Scoring Scheme — Answer

(a) Both models account for:

√ the two laws of reflection
√ the inverse square law of intensities
√ rectilinear propagation
√ absorption and heating
√ specular vs diffuse reflection
light pressure
Snell's Law

(b) The particle model does not explain

√ partial transmission and partial reflection
√ interference
√ diffraction
√ polarization
speed of light in various media

(c) The wave model does not account for

√ transmission of light in the absence of a medium (in vacuum)
photoelectric effect

ELECTRICITY

AND

MAGNETISM

ELECTRIC FIELD AND POTENTIAL

1

S17C
IV.3.c

S 99

F1
A8

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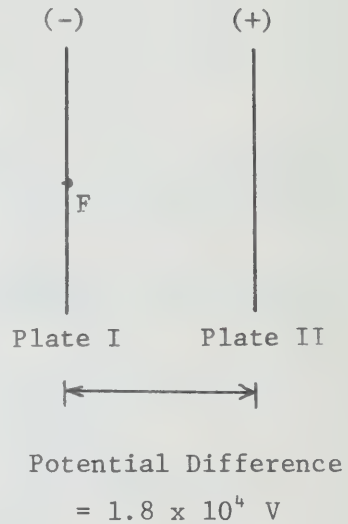
The two parallel plates shown in the diagram are located in a vacuum. Electrons are emitted with negligible kinetic energy from a hot filament at point F on plate I. They are accelerated towards plate II, the anode, by a potential difference of 1.8×10^4 V.

Determine the kinetic energy of an electron, in joules, when it is <u>half way</u> to the anode.

($1 \text{ eV} = 1.60 \times 10^{-19}$ J)



Scoring Scheme	Answer
✓	In going one-half the distance between plates, the electron's change in potential energy is one-half of the total change in electrical potential energy between the plates.
✓ ✓	$\Delta E_e = \frac{1}{2}(qV)$
✓	$= \frac{1}{2}(-1 \text{ e})\ (1.8 \times 10^4 \text{ V})$
✓	$= -0.9 \times 10^4$ eV
✓	$= -0.9 \times 10^4 \text{ eV}\ (1.60 \times 10^{-19} \text{ J/eV})$
✓ ✓ ✓	$= -1.44 \times 10^{-15}$ J
✓	$\Delta E_k = -\Delta E_e$
✓	$E_{k_f} = E_{k_i} + \Delta E_k$
✓	$= 0 + (-\Delta E_e)$
✓	$= +1.4 \times 10^{-15}$ J
✓	The kinetic energy of the electron is 1.4×10^{-15} J.

2 Two parallel metal plates, X and Y, are separated by a distance of 3.2 cm. Plate Y has a positive electrical potential of 200 V with respect to plate X.

S17C
IV.3.e

S 99
95

A8
A11
F1

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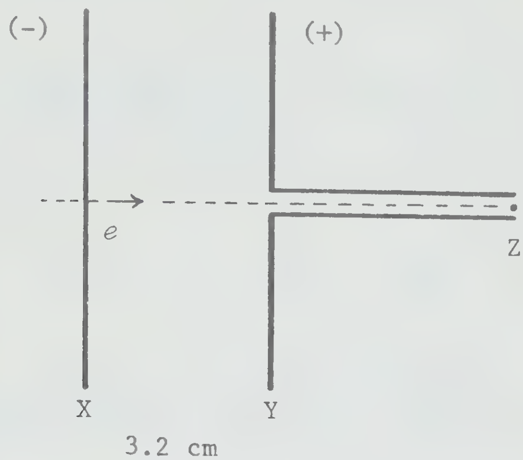
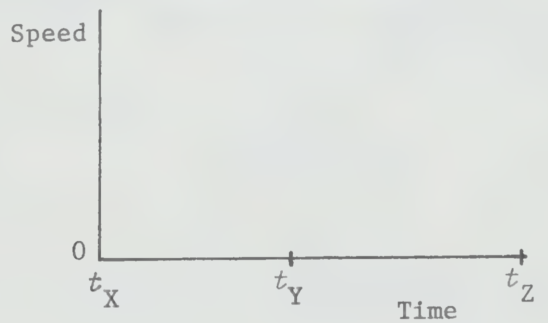


An electron, e, starts from rest at plate X at time t_X, reaches plate Y at time t_Y, and proceeds through a hollow metal tube connected to the plate. It reaches Z at time t_Z.

(a) Using the axes provided, sketch a graph of the speed of the electron versus time for the journey from plate X to plate Y to Z.

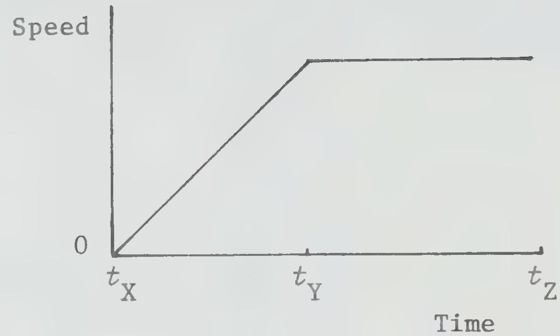


(b) Determine the kinetic energy, in eV, that the electron has when it arrives at plate Y.

(c) Determine the total mechanical energy, in eV, that the electron has when it arrives at plate Y.

(d) Find the magnitude of the electric field between X and Y in units of V/m.

(e) What is the magnitude of the electric field in the tube?

Scoring Scheme	Answer
	(a) 
✓	start at origin
✓	shape from X to Y
✓	shape from Y on: straight, horizontal
	(b) The electron starts from rest and moves toward a position of lower electrical potential energy.
✓	The kinetic energy of the electron when it arrives at plate Y is 200 eV.
	(c) After arriving at plate Y, the electron does not undergo a further drop in electrical potential energy.
✓	The total mechanical energy of the electron when it arrives at plate Y is 200 eV.
✓	(d) $\lvert\vec{E}\rvert = \frac{V}{d}$
✓	$= \frac{200\ \text{V}}{3.2 \times 10^{-2}\ \text{m}}$
✓ ✓	$= 6.3 \times 10^{3}\ \text{V/m}$
✓	The magnitude of the electric field between X and Y is 6.3×10^{3} V/m.
✓	(e) The magnitude of the electric field in the tube is zero.

CURRENT ELECTRICITY AND ELECTROMAGNETISM

1 The scale of a milliammeter is shown below.

S17A
III.2.c

101

B5
A11
G1

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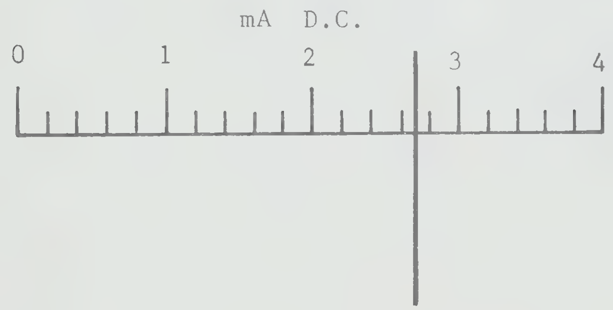

To two significant figures, the reading on the scale is ______________ mA D.C.

Scoring Scheme	Answer
√	2.7

2 The scale of a voltmeter is shown below.

S17A
III.2.c

101

B5
All
G1

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*
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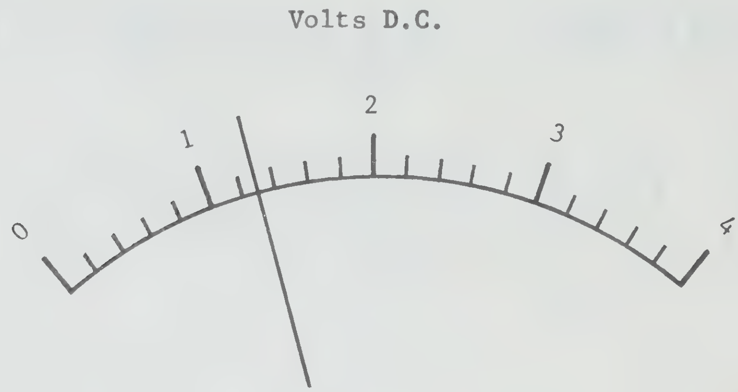

To two significant digits, the reading on the scale is __________ V.

Scoring Scheme	Answer
√ √	1.3

3 The scale of a milliammeter is shown below.

S17A
III.2.c

101

G1
B3
All

mA D.C.

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The current represented by the smallest division on the ammeter scale is ____________ mA D.C.

Scoring Scheme	Answer
✓	40

5 The scale of an ammeter calibrated in milliamperes is shown below.

S17A
III.2.c

101

G1
B3
All

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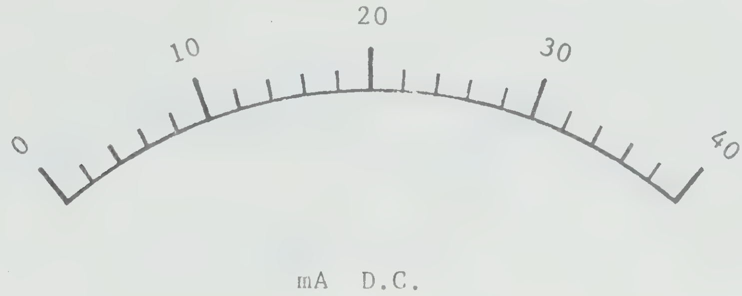

The current represented by the smallest division on the ammeter scale is ___________ mA D.C.

Scoring Scheme	Answer
✓	2

6

S17A
III.2.c

101

G1
B3
All

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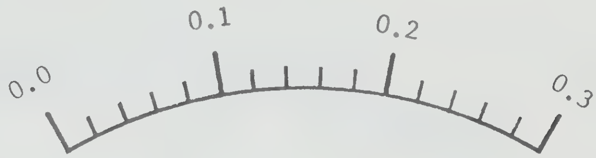
The scale of an ammeter is shown below.



Amperes D.C.

The current represented by the smallest division on the ammeter scale is ______________ A D.C.

Scoring Scheme	Answer
√ √	0.02

7 The scale of an ammeter is shown below.

S17A
III.2.c

101

G1
B3
All

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Amperes D.C.

The current represented by the smallest division on the ammeter scale is ______________ A D.C.

Scoring Scheme	Answer
√ √	0.4

8

S17A
III.2.c

101

G1
B3
All

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*
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The scale of a voltmeter is shown below.

Volts D.C.

The voltage represented by the smallest division on the voltmeter scale is _______________ V D.C.

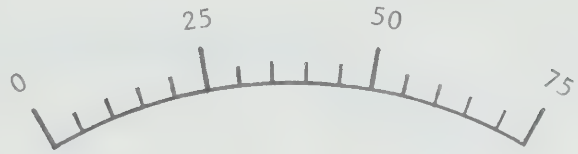
Scoring Scheme	Answer
√	2

9 The scale of a voltmeter is shown below.

S17A
III.2.c

101

G1
B3
A11



Volts D.C.

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** The voltage represented by the smallest division on the voltmeter scale is __________ V D.C.

Scoring Scheme | Answer

√ 5

10 The scale of a voltmeter is shown below.

S17A
III.2.c

101

G1
B3
All

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*
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Volts D.C.

The voltage represented by the smallest division on the voltmeter scale is __________ V D.C.

Scoring Scheme	Answer
√	0.1

11 The scale of a voltmeter is shown below.

S17A
III.2.c

101

G1
B3
A11

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Volts D.C.

The voltage represented by the smallest division on the voltmeter scale is __________ V D.C.

Scoring Scheme	Answer
√	0.2

12 Draw the accepted electrical circuit symbol for a voltmeter.

S17A
III.2.c

S 101

A4
A11

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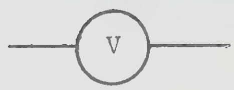
Scoring Scheme	Answer
√	

13

S17A
III.2.c

S 101

A4
A11

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Draw the accepted electrical circuit symbol for a dry cell. Indicate the polarity of the cell on your diagram.

Scoring Scheme

✓ ✓

Answer

14

S17A
III.2.c

S 101

G1

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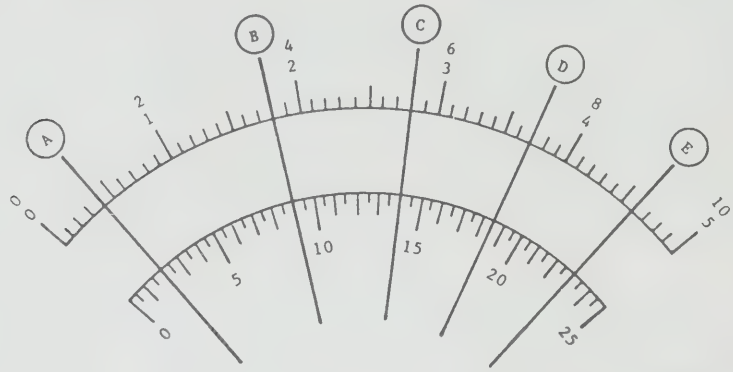
The following diagram represents the needle positions (A, B, C, D or E) and scales that may appear on a multi-range milliammeter.



Complete the chart below by indicating the current reading for each of the needle positions (A, B, C, D or E) and each of the meter range settings shown.

Scoring Scheme	Needle Position	Meter Range Setting	Meter Reading		
√	A	5 mA	____________	mA	(0.40)
√	B	10 mA	____________	mA	(3.60)
√	C	50 mA	____________	mA	(28.0)
√	D	250 mA	____________	mA	(185)
√	E	1000 mA	____________	mA	(920)

15

S17A
III.2.e

104

A2

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State the SI unit of each quantity in the equation $V = IR$.

V ______________

I ______________

R ______________

Scoring Scheme	Answer
√	V: volt or V
√	I: ampere or A
√	R: ohm or Ω

16

S17A
III.2.g

104

A7
F1

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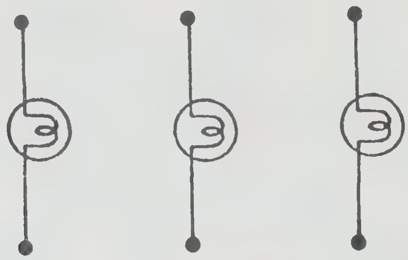
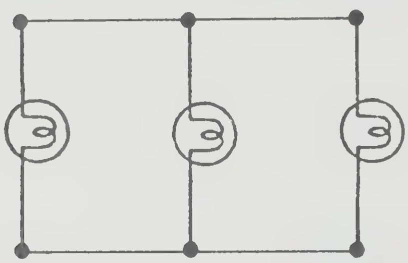
Draw wires on the diagram below to show all three bulbs connected in parallel.



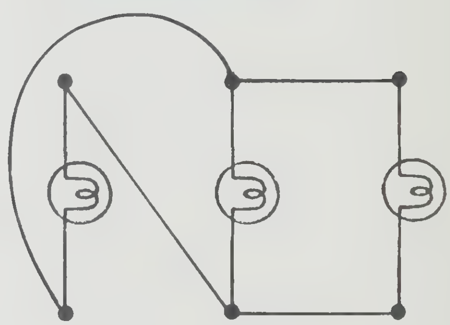
Scoring Scheme

Answer

√ 4 wires connected to yield three current paths



or



17

S17A
III.2.g

104

A7
F1

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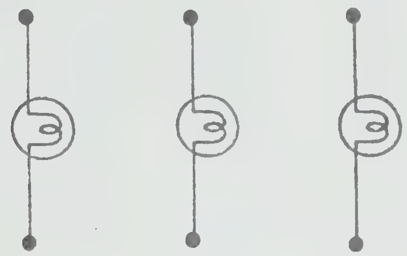
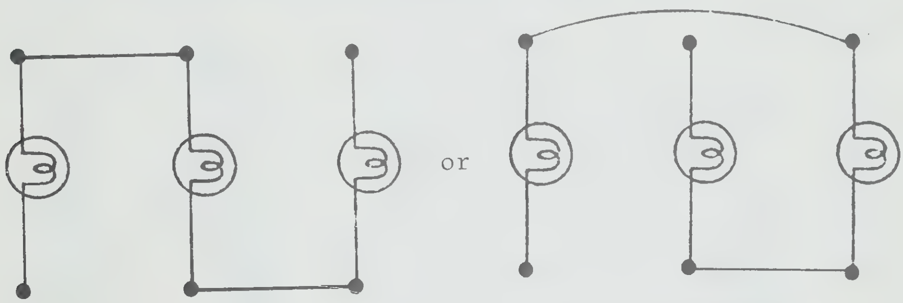
Draw wires on the diagram below to show all three bulbs connected in series.



Scoring Scheme

Answer

√ Two wires connected to yield one current path.



18

S17A
III.2.g

104

A7
F1

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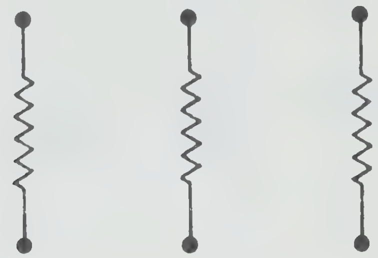
Draw wires on the diagram below to show <u>all</u> resistors connected in parallel.

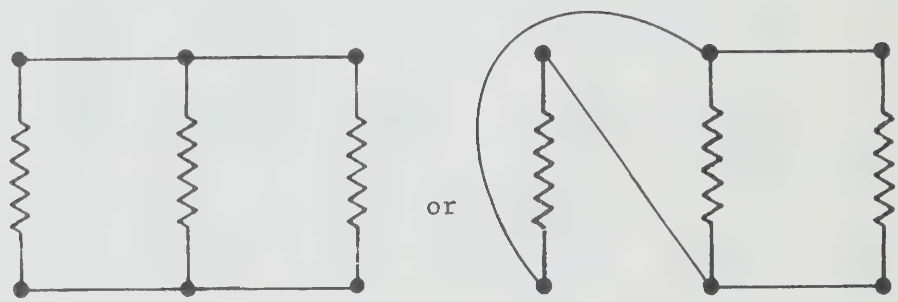


Scoring Scheme

Answer

√

Four wires connected to yield three current paths.



19 Draw wires on the diagram below to show the three resistors connected in series.

S17A
III.2.g

104

A7
F1

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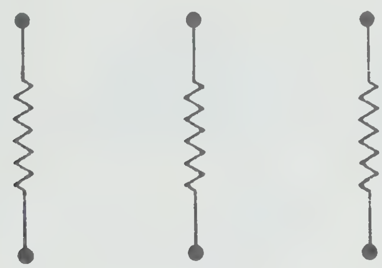
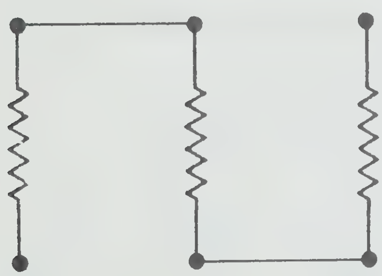


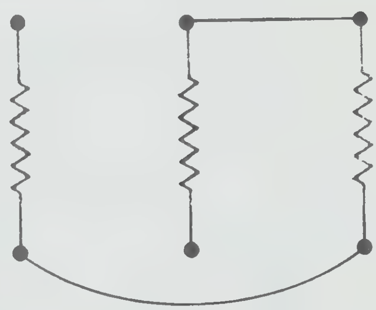
Scoring Scheme

Answer

✓ two wires connected to yield one current path



or



20

S17A
III.2.g

104

A7
A11
F1

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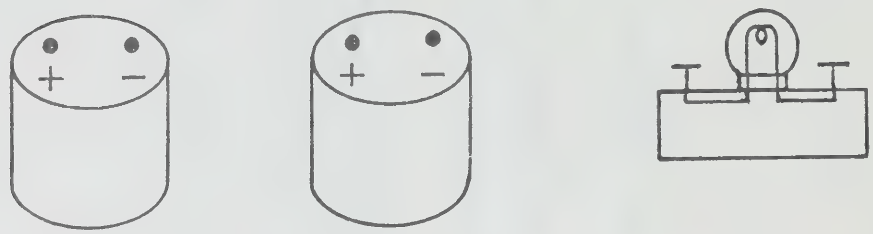
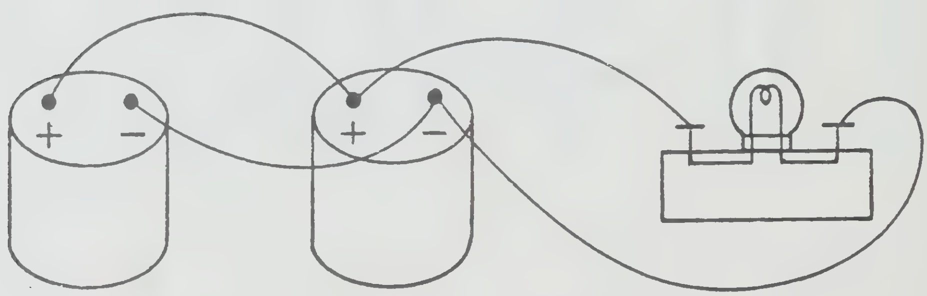
Draw wires on the diagram below to show the two batteries connected in parallel with the bulb.



Scoring Scheme	Answer
√	positive connected to one side of bulb
√	negative connected to other side of bulb
√	positive connected to positive
√	negative connected to negative



21

S17A
III.2.g

104

A7
A11
F1

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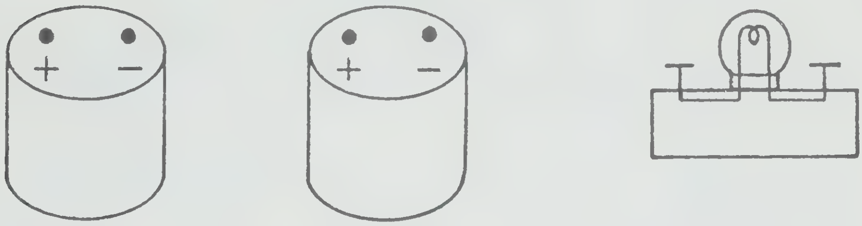
Complete the following diagram by drawing the wires to show the two dry cells connected in series with the bulb.

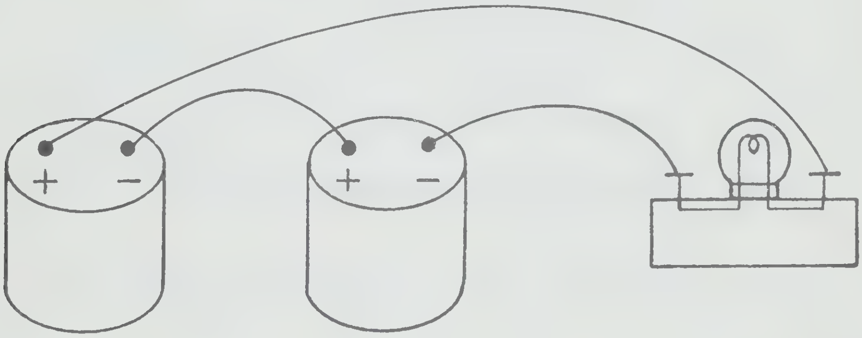


Scoring Scheme

Answer

√ three wires connected to yield one current path

√ positive to negative



22 A circuit containing a power source and four resistors is shown below. The values of the resistances are listed below the diagram.

S17A
III.2.g

104

A8
F1

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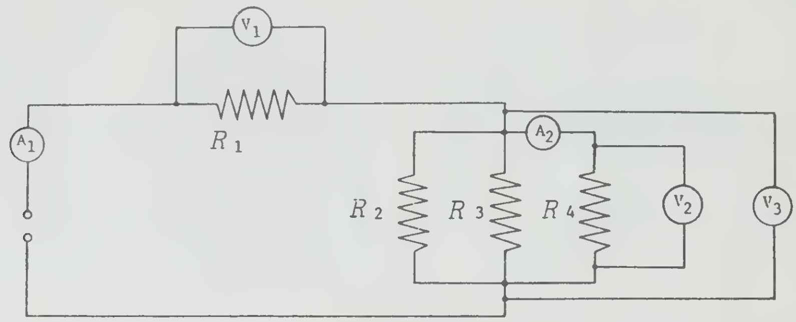

$R_1 = 10\ \Omega$

$R_2 = R_3 = R_4 = 30\ \Omega$

(a) Determine the total effective resistance of the whole circuit.

(b) Determine the reading on ammeter A_1.

(c) Determine the reading on voltmeter V_1.

(d) Determine the reading on the two voltmeters V_2 and V_3.

(e) Determine the reading on ammeter A_2.

Scoring Scheme

Answer

(a) Let I represent current, V represent voltage, R represent resistance, and R_p represent the effective resistance of R_2, R_3, R_4 in parallel.

✓ $$\frac{1}{R_p} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$

✓ $$= \frac{1}{30\ \Omega} + \frac{1}{30\ \Omega} + \frac{1}{30\ \Omega}$$

$$= \frac{3}{30\ \Omega}$$

✓ $$= \frac{1}{10\ \Omega}$$

✓ ✓ $$R_p = 10\ \Omega$$

Scoring Scheme	Answer
	R_T = total effective resistance of whole circuit
√	$= R_1 + R_p$
√	$= 10\ \Omega + 10\ \Omega$
√ √	$= 20\ \Omega$
√	The total effective resistance of the circuit is 20 Ω.
	(b) Let I_1 represent the current through ammeter A_1.
√	$I_1 = I_T$
√	$= \frac{V_T}{R_T}$
√	$= \frac{45\ V}{20\ \Omega}$
√ √	$= 2.25\ A$
√	The reading on ammeter A_1 is 2.3 A.
√	(c) $V_1 = I_1R_1$
√	$= (2.3\ A)\ (10\ \Omega)$
√ √	$= 23\ V$
√	The reading on voltmeter V_1 is 23 V.
√	(d) $V_2 = V_3$
√	$= V_T - V_1$
√	$= 45\ V - 23\ V$
√ √	$= 22\ V$
√	The reading on voltmeters V_2 and V_3 is 22 V each
√	(e) $I_2 = \frac{V_2}{R_4}$
√	$= \frac{22\ V}{30\ \Omega}$
√ √	$= 0.73\ A$
√	The reading on ammeter A_2 is 0.73 A.

23

S17A
III.3.j

104
102
101
99

Column I lists a number of quantities to be measured. Column II lists a number of instruments available for making measurements.

In the space provided before each item in Column I, write the letter corresponding to the instrument from Column II which is most suitable for that measurement. A particular instrument may be used once, more than once, or not at all.

B4
A2 Answer & Scoring Scheme
F1
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Answer & Scoring Scheme		I Quantity to be measured	II Measuring Instruments available
√ (A)	______	1. The potential difference across a resistor connected to a battery	(A) DC voltmeter
√ (B)	______	2. The current through a resistor connected to a battery	(B) DC ammeter
√ (E)	______	3. The direction of the magnetic field near a wire conducting a current	(C) AC voltmeter
√ (G)	______	4. The resistance of a resistor	(D) AC ammeter
√ (F)	______	5. The direction of electron flow induced in a coil by a moving magnet	(E) Magnetic Compass
√ (C)	______	6. The potential difference provided by an electrical outlet in your home	(F) Galvanometer
√ (D)	______	7. The current drawn by a hair dryer when connected to an electrical outlet in your home	(G) Ohmmeter
√ (C)	______	8. The potential difference across the secondary coil of a transformer when the primary coil is connected to an electrical outlet in your home	(H) Electroscope

24

S17A
III.2.g

104

F1
A7

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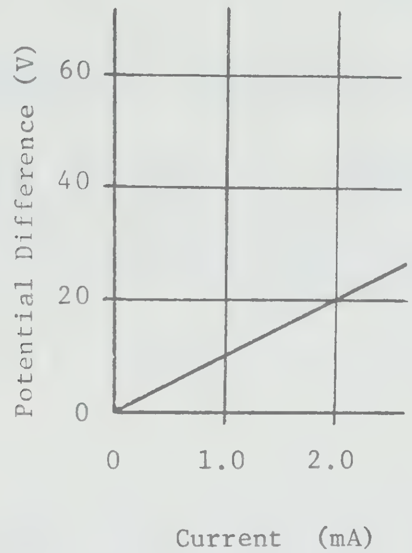
The graph of potential difference versus current for a resistor is shown below.



Calculate the resistance of the resistor in ohms.

Scoring Scheme	Answer
	$\text{Resistance} = \dfrac{\text{Rise}}{\text{Run}}$
√	$= \dfrac{\Delta V}{\Delta I}$
√	$= \dfrac{20\ \text{V}}{2.0\ \text{mA}}$
√	$= \dfrac{20\ \text{V}}{2.0 \times 10^{-3}\ \text{A}}$
	$= 10 \times 10^{3}\ \Omega$
√ √	$= 1.0 \times 10^{4}\ \Omega$
√	The resistor has a resistance of $1.0 \times 10^{4}\ \Omega$.

25

S17A
III.2.g

104

F1
A8

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Five identical resistors are connected in parallel to a 3.0 V battery. The current leaving the battery is 7.5 mA. When a sixth identical resistor is connected into the circuit, the total current becomes 9.0 mA.

(a) How is the sixth resistor connected to the others? Explain your reasoning.

(b) Calculate the current through the sixth resistor. Explain your solution.

(c) What is the potential difference across the sixth resistor? How do you know?

(d) Calculate the resistance of the sixth resistor.

Scoring Scheme	Answer
√ √ √	(a) The sixth resistor is connected in parallel. Since the total current leaving the battery has increased, the effective resistance of the circuit has decreased. The effective resistance is decreased by connecting resistors in parallel.
√	(b) Since six identical resistors are connected in parallel one-sixth of the current goes through each resistor.
	Solution I / Solution II
√	$I = \frac{\text{total current}}{6}$ / $I = I_{6 \text{ resistors}} - I_{5 \text{ resistors}}$
√	$= \frac{9.0 \text{ mA}}{6}$ / $= 9.0 \text{ mA} - 7.5 \text{ mA}$
√ √	$= 1.5 \text{ mA}$ / $= 1.5 \text{ mA}$
√	The current through each resistor is 1.5 mA.
√	(c) The potential difference across the sixth resistor is 3.0 V.
√ √	The potential difference across each resistor is the same and is equal to the voltage of the source.
	(d) $V = 3.0$ V
	$I = 1.5$ mA
√	$= 1.5 \times 10^{-3}$ A

Scoring Scheme	Answer
✓	$R = \frac{V}{I}$
✓	$= \frac{3.0 \text{ V}}{1.5 \times 10^{-3} \text{ A}}$
✓ ✓	$= 2.0 \times 10^{3}\ \Omega$
✓	The resistance of the sixth resistor is $2.0 \times 10^{3}\ \Omega$.

26 The resistance from head to toe of a typical human body with wet skin is 1000 Ω.

S17A
III.2.g What current would flow through a body connected to a 12.0 V D.C. battery?

104

F1
A8
A2

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Scoring Scheme	Answer
	$R = 1000\ \Omega$
✓	
	$V = 12.0$ V D.C.
✓	$I = \frac{V}{R}$
✓	$= \frac{12.0\ \text{V}}{1000\ \Omega}$
	$= 0.0120$ A
✓ ✓	$= 1.20 \times 10^{-2}$ A
✓	A current of 1.20×10^{-2} A would flow through the body.

27

S17A
III.2.g

104

F1
A8
A3

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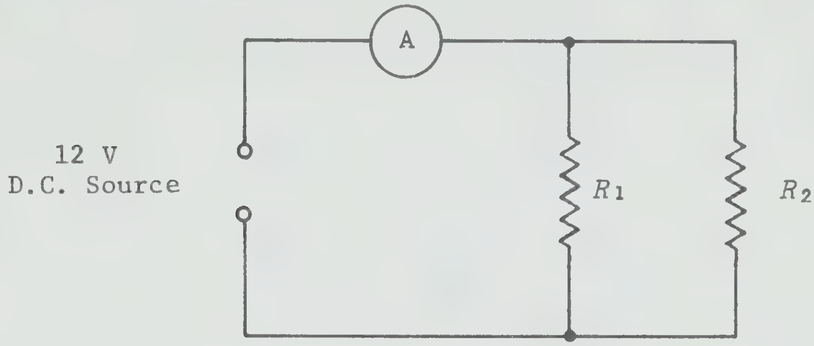
Consider the following circuit in which $R_1 = 4.0\ \Omega$ and the reading on ammeter A is 4.0 A.



(a) What is the current through R_1?

(b) What is the current through R_2?

(c) What is the value of R_2?

Scoring Scheme | Answer

✓ (a) $R_1 = 4.0\ \Omega$ $V = 12\text{ V D.C.}$

✓ $I_1 = \dfrac{V}{R_1}$

✓ $= \dfrac{12\text{ V}}{4.0\ \Omega}$

✓ ✓ $= 3.0\text{ A}$

✓ The current through R_1 is 3.0 A.

✓ (b) $I_t = 4.0\text{ A}$ $I_1 = 3.0\text{ A}$

✓ $I_t = I_1 + I_2$

✓ $I_2 = I_t - I_1$

✓ $= 4.0\text{ A} - 3.0\text{ A}$

✓ ✓ $= 1.0\text{ A}$

✓ The current through R_2 is 1.0 A.

Scoring Scheme	Answer	
✓	(c) $I_2 = 1.0\ \text{A}$	$V = 12\ \text{V D.C.}$
✓	$R_2 = \dfrac{V}{I_2}$	
✓	$= \dfrac{12\ \text{V}}{1.0\ \text{A}}$	
✓ ✓	$= 12\ \Omega$	
✓	The value of R_2 is $12\ \Omega$.	

28

S17A
III.2.g

104

F1
A8
A3

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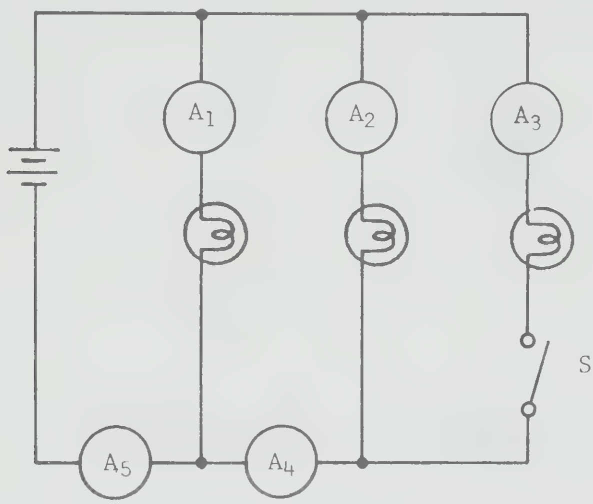
Consider the following circuit in which all light bulbs are identical and the ammeter A_1 reads 250 mA when the switch S is open.



Scoring Scheme			Answer
	(a) With the switch S open,		
✓	A_3 reads	________	(zero)
✓ ✓	A_4 reads	________	(250 mA)
✓ ✓	A_5 reads	________	(500 mA)
	(b) If the switch S is closed,		
✓ ✓	A_3 reads	________	(250 mA)
✓ ✓	A_4 reads	________	(500 mA)
✓ ✓	A_5 reads	________	(750 mA)

29 Consider the following circuit diagram.

S17A
III.2.g

104

F1
A8
A3

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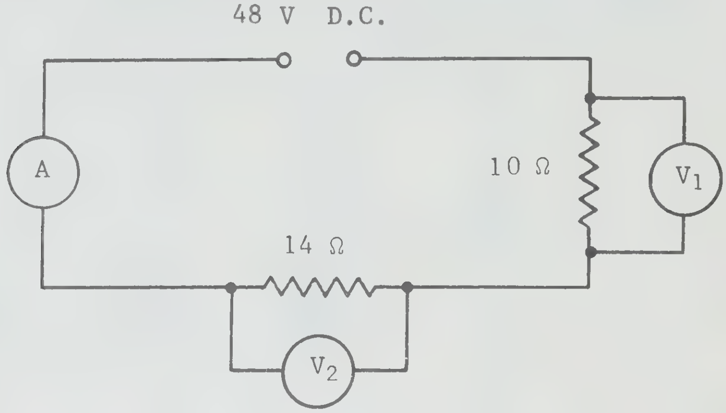

Scoring Scheme | Answer

If the reading on V_1 is 20 V,

√ √ the reading on V_2 is ________________ (28 V)

√ √ the reading on A is ________________ (2.0 A)

30

S17A
III.2.g

104
105

F3
A3

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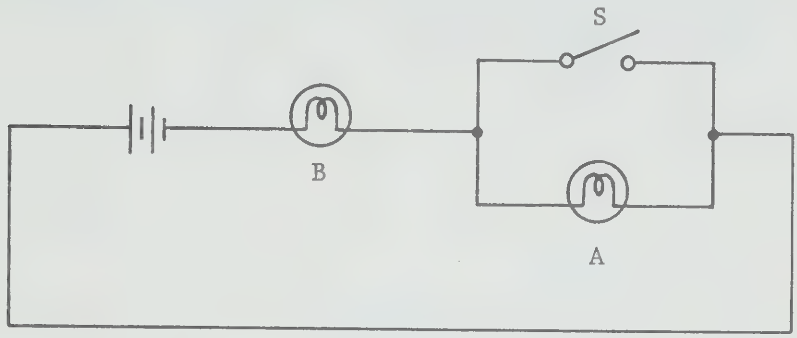
Two identical light bulbs A and B are connected as shown in the following diagram.



(a) (i) If the switch S is closed what change, if any, will occur in the intensity with which A glows?

(ii) Explain your answer.

(b) (i) If the switch S is closed what change, if any, will occur in the intensity with which B glows?

(ii) Explain your answer.

Scoring Scheme	Answer
✓	(a) (i) When S is closed, A stops glowing.
✓ ✓	(ii) When S is closed, a path of almost zero resistance in parallel with A exists. As a result the electron flow through A approaches zero.
✓	(b) (i) When S is closed, B glows more brightly.
✓ ✓	(ii) Closing S reduces the effective resistance of the circuit. As a result the current through B increases.

31 In the space provided, draw the accepted electrical circuit symbol for each of the following components of a simple circuit.

S17A
III.2.e

S 104

A4
A11

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(a) a wire crossing, but not connected to another wire

(b) a lamp

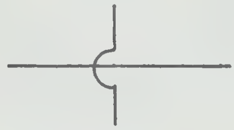
(c) a fuse

(d) an open switch

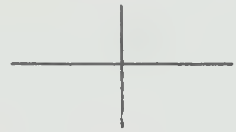
(e) a resistor

(f) an ammeter

Scoring Scheme	Answer
√	(a) a wire crossing, but not connected to another wire



or



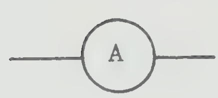
√	(b) a lamp

√	(c) a fuse

√	(d) an open switch

√	(e) a resistor

√	(f) an ammeter



32 The graphs of potential difference versus current for four different resistors A, B, C and D, are shown below.

S17A
III.2.g

S 104

A11
A7

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-
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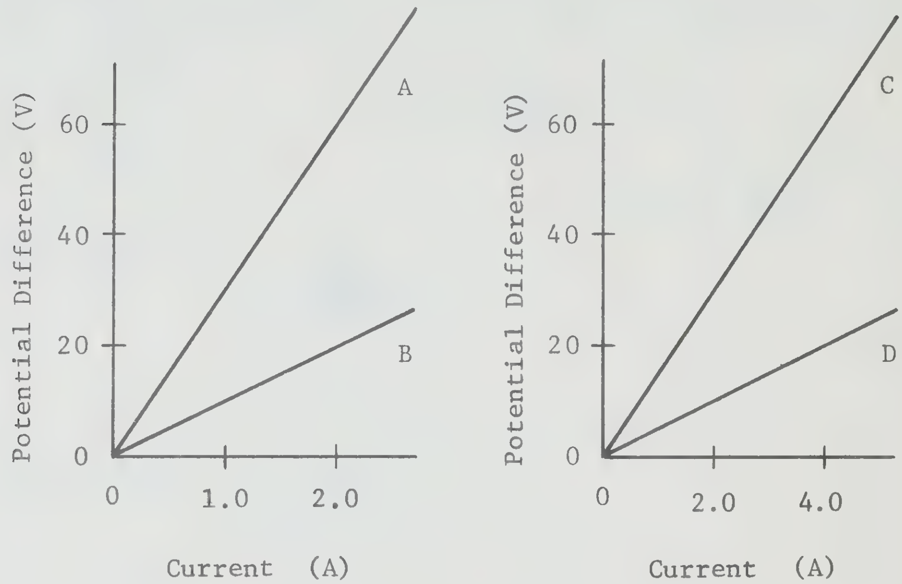

Which of the four resistors has the highest resistance? ________

Scoring Scheme	Answer
✓	A

33

S17A
III.2.g

S 104

A11
A7

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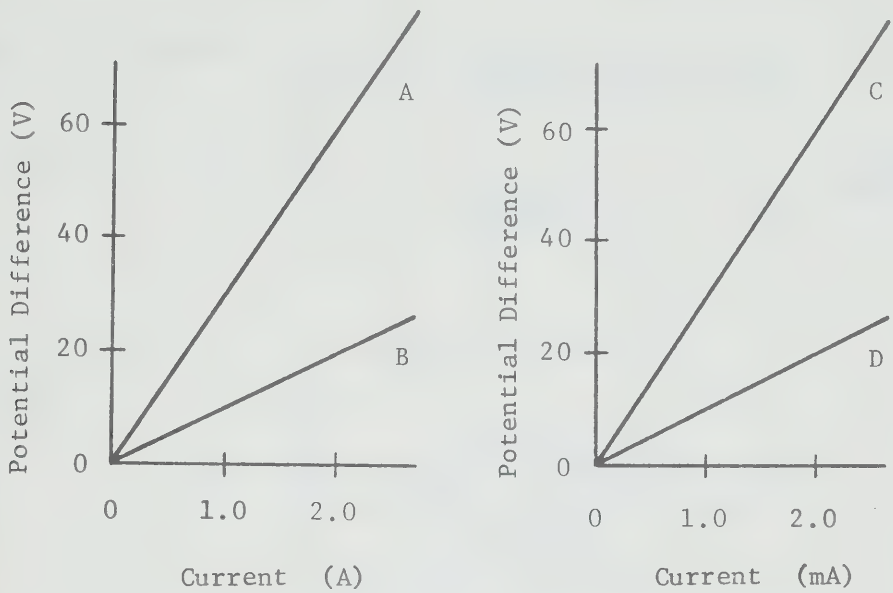
**

The graphs of potential difference versus current for four different resistors A, B, C and D are shown below.



Which of the four resistors has the lowest resistance? ____________

Scoring Scheme

√ B

34

S17A
III.2.g

The following circuit diagrams show various arrangements and orientations of dry cells. Assume that the potential difference across a single dry cell is 1.5 V.

S 104

What is the reading on the voltmeter V in each of the circuits shown?

F1
A4 Scoring Scheme

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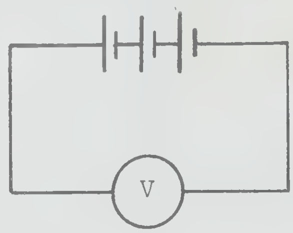
** ✓

Answer

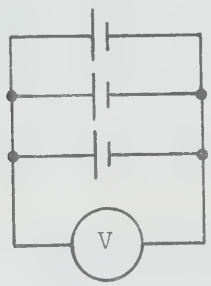
(1)



V = ________ V (4.5 V)

✓

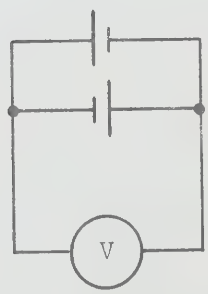
(2)



V = ________ V (1.5 V)

✓

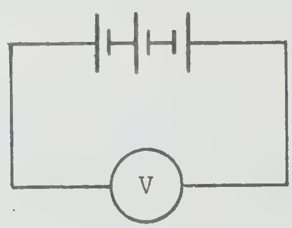
(3)



V = ________ V (0)

✓

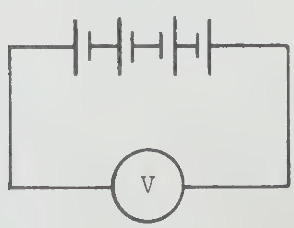
(4)



V = ________ V (1.5 V)

✓

(5)



V = ________ V (0)

35

S17A
III.2.e

S 104

F1
A8

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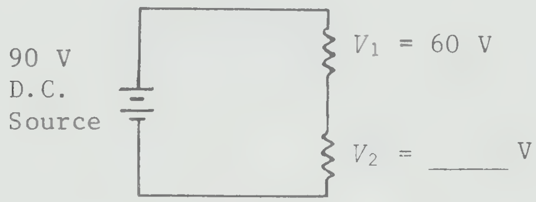
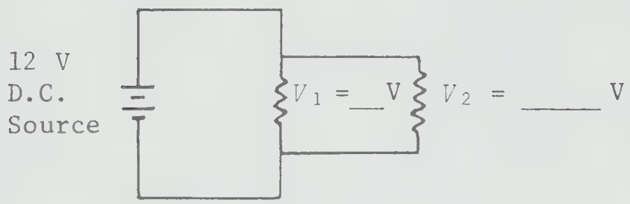
**

For each of the following circuit diagrams, determine the value of the unknown quantities. Enter your answers in the spaces provided.

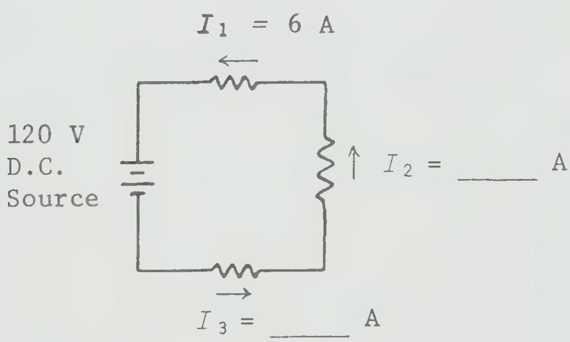
(a)



(b)



(c)



Scoring Scheme	Answer
√	(a) V_2 = 30 V
√	(b) V_1 = 12 V
√	V_2 = 12 V
√	(c) I_2 = 6 A
√	I_3 = 6 A

36

State the SI unit of each quantity in the equation $P = VI$.

S17A
III.2.h

105

A2

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-
*

P ____________

V ____________

I ____________

Scoring Scheme	Answer
✓	P: watt or W
✓	V: volt or V
✓	I: ampere or A

37 State the SI unit of each quantity in the equation $E = Pt$.

S17A
III.2.h

105

A2
A8

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-
*

E ____________

P ____________

t ____________

Scoring Scheme	Answer
√	E: joule or J
√	P: watt or W
√	t: second or s

38

S17A
III.2.h

S 105

A11
A8

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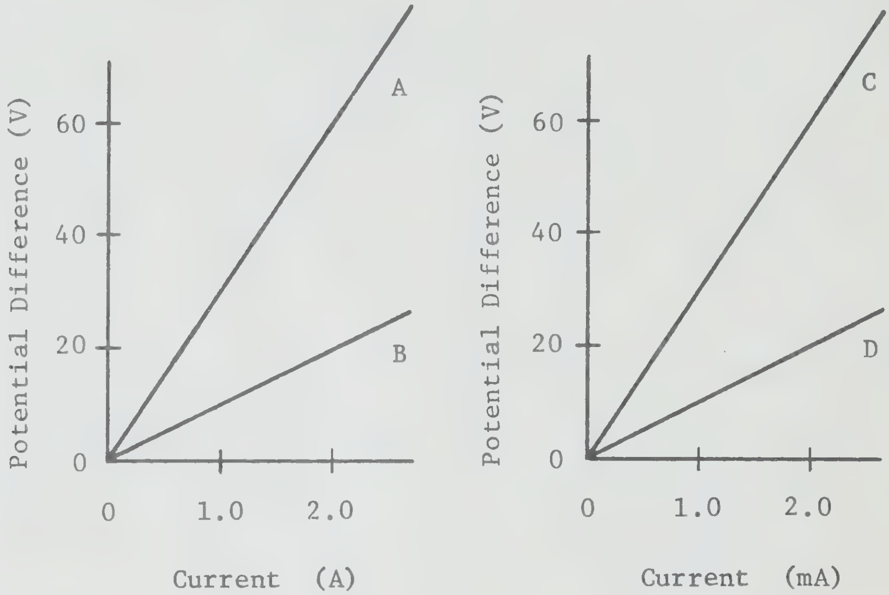
The graphs of potential difference versus current for four different resistors A, B, C and D are shown below.



(a) If each of the four resistors were individually connected to identical batteries for the same length of time, which resistor would get the hottest?

(b) Explain your answer to (a).

Scoring Scheme	Answer
√	(a) B
√	(b) B has the lowest resistance.
√ √	The smaller the resistance, the larger the current
√	and the larger the rate of energy consumption (P)
√	for a constant V ($P = V^2/R$).

39 A television set draws a current of 2.0 A when connected to 110 V.

S17A
III.2.h What is the cost of operating the set for 10 h if electricity costs 1.5¢ per MJ?

106

F1
A8

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-
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Scoring Scheme — Answer

✓ $E_e = VIt$

✓ $= (110\ \text{V})\ (2.0\ \text{A})\ (10\ \text{h})$

✓ $= (110\ \frac{\text{J}}{\text{C}})\ (2.0\ \frac{\text{C}}{\text{s}})\ (10\ \text{h})\ (3600\ \frac{\text{s}}{\text{h}})$

✓ $= (110)\ (2.0)\ (10)\ (3600)\ \text{J}$

✓ $= \dfrac{(110)\ (2.0)\ (10)\ (3600)\ \text{J}}{1\ 000\ 000\ \text{MJ/J}}$

✓ ✓ $= 7.92\ \text{MJ}$

✓ Cost = energy consumed x rate

✓ = 7.92 MJ x 1.5¢/MJ

= 11.9¢

✓ ✓ = 12¢

✓ The cost of operating the set for 10 h is 12¢.

40

S17A
III.2.h

106

F3
A4
B3

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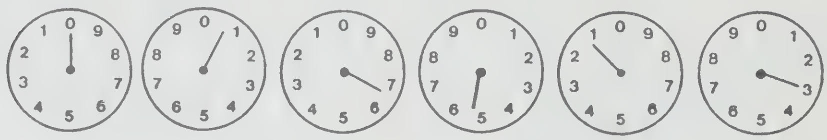
**

At the beginning of a billing period, a six dial electricity energy meter (reading kW·h) appears as shown below.

At the end of a billing period the same electricity meter appears as shown below.



Electricity costs 9¢ per kW·h for the first 100 kW·h, 5¢ per kW·h for the next 400 kW·h, and 3¢ per kW·h for the remainder.

(a) What is the reading on the meter at the beginning and the end of the billing period?

(b) What is the total energy consumption during the billing period?

(c) What is the total cost for this energy in dollars? Show your calculations.

Scoring Scheme	Answer
√ √	(a) The reading on the meter is 005963 kW·h at the beginning, and 006513 kW·h at the end of the billing period.
√	(b) The total energy consumption during the billing period is 550 kW·h.
√	(c) 100 kW·h x 9¢/kW·h = 900¢
√	400 kW·h x 5¢/kW·h = 2000¢
√	50 kW·h x 3¢/kW·h = 150¢
√	3050¢
√	= $30.50
√	The total cost for this energy is $30.50.

41

S17A
III.2.h

106

F3
A4
B3

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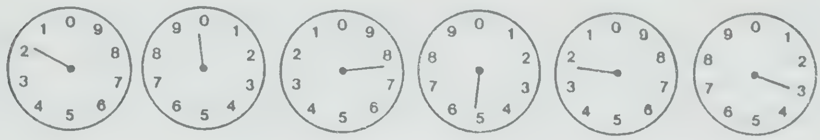
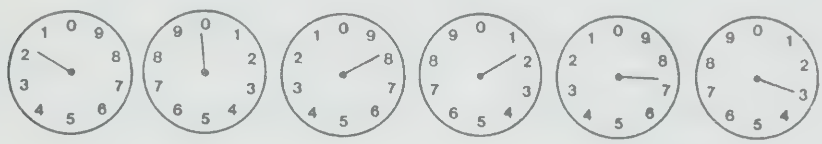
**

At the beginning of a billing period, a six dial electricity energy meter (reading kW·h) appears as shown below.



At the end of the billing period the meter appears as shown below.



Electricity costs 9¢ per kW·h for the first 100 kW·h, 5¢ per kW·h for the next 400 kW·h, and 3¢ per kW·h for the remainder.

(a) What is the reading on the meter at the beginning and the end of the billing period?

(b) What is the total energy consumption during the billing period?

(c) What is the total cost for this energy in dollars? Show your calculations.

Scoring Scheme	Answer
√ √	(a) The reading on the meter is 197523 kW·h at the beginning, and 198173 kW·h at the end of the billing period.
√	(b) The total energy consumption during the billing period is 650 kW·h.
√	(c) 100 kW·h x 9¢/kW·h = 900¢
√	400 kW·h x 5¢/kW·h = 2000¢
√	150 kW·h x 3¢/kW·h = 450¢
√	3350¢
√	= $33.50
√	The total cost for this energy is $33.50.

42

S17A
III.2.h

106

F3
A4
B3

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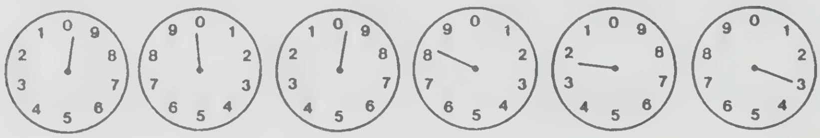
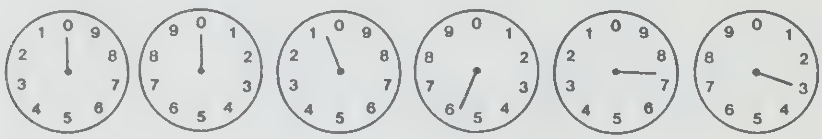
At the beginning of a billing period, a six dial electricity energy meter (reading kW·h) appears as shown below.



At the end of the billing period the meter appears as shown below.



Electricity costs 9¢ per kW·h for the first 100 kW·h, 5¢ per kW·h for the next 400 kW·h, and 3¢ per kW·h for the remainder.

(a) What is the reading on the meter at the beginning and the end of the billing period?

(b) What is the total energy consumption during the billing period?

(c) What is the total cost for this energy in dollars? Show your calculations.

Scoring Scheme	Answer
√ √	(a) The reading on the meter is 999823 kW·h at the beginning, and 000573 kW·h at the end of the billing period.
√ √	(b) The total energy consumption during the billing period is 750 kW·h.
√	(c) 100 kW·h x 9¢/kW·h = 900¢
√	400 kW·h x 5¢/kW·h = 2000¢
√	250 kW·h x 3¢/kW·h = 750¢
√	3650¢
√	= $36.50
√	The total cost for this energy is $36.50.

43

S17A
III.3.c

108
101
36
31

B4
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Column I lists a number of quantities to be measured. Column II lists a number of instruments available for making measurements.

In the space provided before each item in Column I, write the letter corresponding to the instrument from Column II which is most suitable for that measurement. A particular instrument may be used once, more than once, or not at all.

Answer & Scoring Scheme	I Quantity to be measured	II Measuring Instruments available
√ (L)	______ 1. DC current of 1.7 mA	(A) equal arm balance
√ (F)	______ 2. The thickness of a single page	(B) electroscope
		(C) compass
√ (I)	______ 3. The time required for a small metal ball to fall 3 m through the air	(D) AC ammeter
		(E) spring scale
√ (M)	______ 4. The amplitude of vibration of a mass suspended on the end of a spring	(F) micrometer
		(G) DC milliammeter with a 0-1 mA scale
√ (N)	______ 5. The angle between two straight lines on a page	(H) stopwatch calibrated to 0.2 s intervals
√ (A)	______ 6. The mass of a cart	(I) stopwatch calibrated to 0.1 s intervals
√ (J)	______ 7. The potential difference provided by a single dry cell	(J) DC voltmeter with 0-4 V scale
√ (C)	______ 8. The direction of the magnetic field around a wire carrying a current	(K) DC voltmeter with 0-30 V scale
√ (E)	______ 9. The force of gravity acting on a body	(L) DC milliammeter with 0-3 mA scale
		(M) metre stick
		(N) protractor

WAVE/PARTICLE DUALITY

OF

ELECTROMAGNETIC

RADIATION AND MATTER

PHOTONS

1

S17C
IV.6.c

118
116

A8
D3
D4

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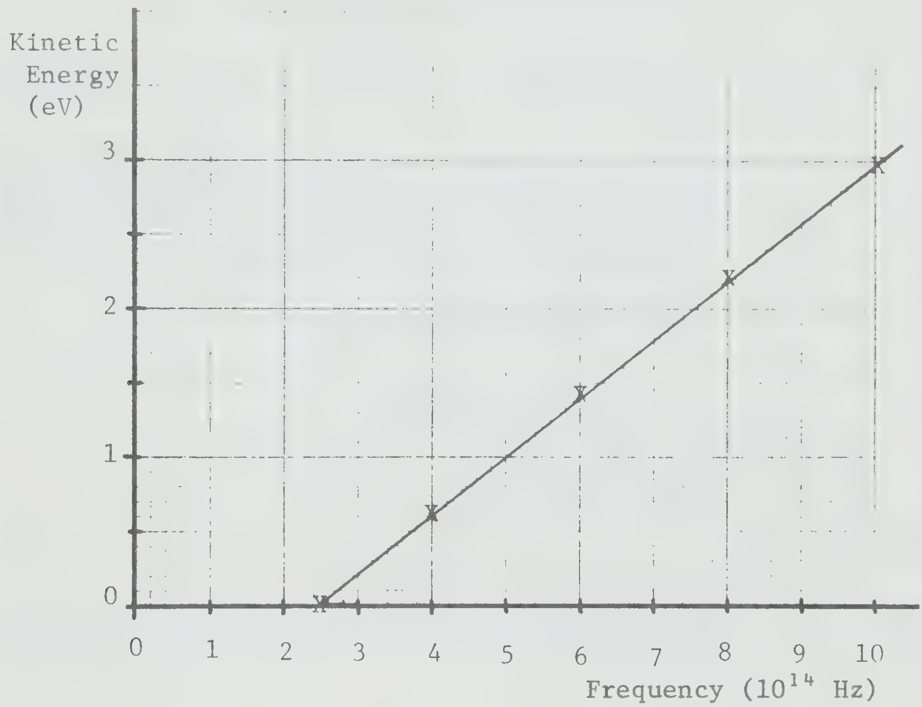
The graph shows the kinetic energy of the most energetic photoelectrons as a function of the frequency of the light falling on the cathode in a photoelectric cell.



(a) According to the graph, what threshold potential difference would be required to stop all the emitted electrons if the incident light had a frequency of 7.5×10^{14} Hz?

(b) What is the physical significance of the intercept of the graph with the frequency axis (x axis)?

(c) What is the physical significance of the intercept obtained when the graph is extrapolated back to the kinetic energy axis (y axis)?

(d) Use the graph to determine a value for Planck's constant.

Scoring Scheme	Answer
✓ ✓	(a) A potential difference of 2.0 V is required to stop all the emitted electrons for light of this frequency.
✓	(b) The energy binding the electrons to the atom must first be overcome before any electrons are released.
✓ ✓	The energy used to overcome the binding energy must be supplied by the photons from the light source. Only photons of frequency 2.5×10^{14} Hz or greater have enough energy to eject electrons.
✓ ✓	(c) The y-intercept gives the work function energy of the metal.
✓ ✓	The work function of a metal is the minimum energy which must be supplied to free electrons in the metal to enable them to escape from the metal. The work function is different for different metals.
✓	(d) h = slope of the graph (since $E = hf$)
✓ ✓	$= \dfrac{(3 - 1)\text{ eV}}{(10 - 5) \times 10^{14}\text{ Hz}}$
	$= \dfrac{2\text{ eV}}{5 \times 10^{14}\text{ Hz}}$
✓ ✓	$= 4 \times 10^{-15}$ eV·s
✓	The value for Planck's constant is 4×10^{-15} eV·s.

2

S17C
IV.6.c

118

F1
A8

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Radiation of frequency 4.0×10^{14} Hz strikes a metal whose threshold energy is 1.2 eV.

Determine the maximum kinetic energy of the ejected photoelectrons ($h = 4.1 \times 10^{-15}$ eV·s).

Scoring Scheme	Answer
	$f = 4.0 \times 10^{14}$ Hz
✓	$B = 1.2$ eV
	$h = 4.1 \times 10^{-15}$ eV·s
✓	$E_{k(\text{photo-electrons})} = h_f - B$
✓	$= (4.0 \times 10^{14}\text{ Hz})(4.1 \times 10^{-15}\text{ eV·s}) - 1.2\text{ eV}$
	$= 16.4 \times 10^{-1}\text{ eV} - 1.2\text{ eV}$
✓ ✓	$= 0.4$ eV
✓	The maximum kinetic energy of the photoelectrons ejected is 0.4 eV.

3 A photon in a vacuum has a frequency of 9.0×10^{14} Hz. ($h = 6.62 \times 10^{-34}$ J·s; $c = 3.0 \times 10^{8}$ m/s)

S17C
IV.6.d For this photon

120 (a) what is the wavelength?
70

(b) what is the momentum?

F1
A8 (c) what is the energy?

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**
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Scoring Scheme	Answer
√	$f = 9.0 \times 10^{14}$ Hz $c = 3.0 \times 10^{8}$ m/s $h = 6.62 \times 10^{-34}$ J·s
√	(a) $\lambda = \frac{c}{f}$
√	$= \frac{3.0 \times 10^{8}\ \text{m/s}}{9.0 \times 10^{14}\ \text{Hz}}$
√ √	$= 3.3 \times 10^{-7}$ m
√	The wavelength of the photon is 3.3×10^{-7} m.
√	(b) $p = \frac{hf}{c}$
√	$= \frac{(6.62 \times 10^{-34}\ \text{J·s})(9.0 \times 10^{14}\ \text{Hz})}{(3.0 \times 10^{8}\ \text{m/s})}$
√ √	$= 2.0 \times 10^{-27}$ kg·m/s
√	The momentum of the photon is 2.0×10^{-27} kg·m/s.
√	(c) $E = hf$
√	$= 6.62 \times 10^{-34}$ J·s $\times 9.0 \times 10^{14}$ Hz
√ √	$= 6.0 \times 10^{-19}$ J
√	The energy of the photon is 6.0×10^{-19} J.

4

S17C
IV.6.c

120
116

F1
A8
A3

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A particular photon of electromagnetic radiation has a frequency of 3.0×10^{16} Hz. ($h = 6.63 \times 10^{-34}$ J·s), $c = 3.0 \times 10^{8}$ m/s)

(a) Determine the energy of this photon.

(b) Determine the momentum of this photon.

Scoring Scheme	Answer
	$f = 3.0 \times 10^{16}$ Hz
✓	$c = 3.0 \times 10^{8}$ m/s
	$h = 6.63 \times 10^{-34}$ J·s
✓	(a) $E = hf$
✓	$= (6.63 \times 10^{-34}\ \text{J·s})(3.0 \times 10^{16}\ \text{Hz})$
	$= 19.89 \times 10^{-18}$ J
	$= 1.989 \times 10^{-17}$ J
✓ ✓	$= 2.0 \times 10^{-17}$ J
✓	The energy of the photon is 2.0×10^{-17} J.
	(b) $p = \frac{h}{\lambda}$
✓	$= \frac{hf}{c}$
	$= \frac{E}{c}$
✓	$= \frac{1.99 \times 10^{-17}\ \text{J}}{3.0 \times 10^{8}\ \text{m/s}}$
✓	$= 0.663 \times 10^{-25}$ kg·m/s
✓ ✓	$= 6.6 \times 10^{-26}$ kg·m/s
✓	The momentum of the photon is 6.6×10^{-26} kg·m/s.

5 A particular photon has 2.0 eV of energy. Determine the momentum of this photon in kg·m/s.
($1\ eV = 1.60 \times 10^{-19}\ J$, $c = 3.0 \times 10^{8}\ m/s$)

S17C
IV.6.d

120

F1
A8
A3

-
**
-

Scoring Scheme	Answer
	$1\ eV = 1.60 \times 10^{-19}\ J$
✓	$E = 2.0\ eV$
	$c = 3.0 \times 10^{8}\ m/s$
✓	$p = \frac{E}{c}$
✓	$= \frac{(2.0\ eV)\ (1.60 \times 10^{-19}\ J/eV)}{(3.0 \times 10^{8}\ m/s)}$
	$= 1.067 \times 10^{-27}\ kg \cdot m/s$
✓ ✓	$= 1.1 \times 10^{-27}\ kg \cdot m/s$
✓	The momentum of the photon is 1.1×10^{-27} kg·m/s.

2

S17A
I.3.c
S17C
III.6.f

S 431
S 106

C4

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-
**

List the steps an electrician might use to measure the energy used by an electric clothes dryer during a full drying cycle?

Scoring Scheme	Sample Answers
√	1. (a) Remove the fuses (or switch off the circuit breakers) from all the circuits in the main electrical panel, except the one operating the electric dryer.
√	(b) Note the reading on the electrical energy meter installed for the home.
√	(c) Operate the electric clothes dryer for a full drying cycle.
√	(d) Repeat (b) at the end of the cycle.
√	(e) Subtract the initial energy reading from the final energy reading to obtain actual energy used.
√	(f) Replace all fuses.
√ √	2. (a) Connect a wattmeter into the electric dryer circuit.
√	(b) Measure the time taken for the electric clothes dryer to complete a full drying cycle.
√	(c) Note the wattmeter reading while the dryer is operating.
√ √	(d) Calculate the electrical energy used. ($E = Pt$)
√√√√ √	3. Use the same method as solution #2 above, but use a voltmeter and ammeter to measure voltage and current separately, and use $P = VI$ to obtain the power.

6

A particular photon has a wavelength of 700 nm. Determine the momentum of this photon in kg·m/s. (h = 6.6 x 10^{-34} J·s)

S17C
IV.6.d

120

F1
A8
A3

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Scoring Scheme	Answer	
✓	$\lambda = 700$ nm	$h = 6.6 \times 10^{-34}$ J·s
✓	$= 700 \times 10^{-9}$ m	
✓	$p = \frac{h}{\lambda}$	
✓	$= \frac{6.6 \times 10^{-34}\ \text{J·s}}{700 \times 10^{-9}\ \text{m}}$	
✓ ✓	$= 9.4 \times 10^{-28}$ kg·m/s	
✓	The momentum of the photon is 9.4×10^{-28} kg·m/s.	

7

S17C
IV.6.d

120

F1
A8
A3

-
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Determine the momentum of a photon having a frequency of 1.5×10^{14} Hz. ($h = 6.6 \times 10^{-34}$ J·s, $c = 3.0 \times 10^{8}$ m/s)

Scoring Scheme	Answer
	$f = 1.5 \times 10^{14}$ Hz
✓	$h = 6.6 \times 10^{-34}$ J·s
	$c = 3.0 \times 10^{8}$ m/s
✓	$p = \frac{hf}{c}$
✓	$= \frac{(6.6 \times 10^{-34} \text{ J·s})(1.5 \times 10^{14} \text{ Hz})}{3.0 \times 10^{8} \text{ m/s}}$
✓ ✓	$= 3.3 \times 10^{-28}$ kg·m/s
✓	The momentum of the photon is 3.3×10^{-28} kg·m/s.

8

S17C
IV.6.d

120

F1
A8
A3

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Determine the momentum of a photon which has an energy of 8.0 eV. (h = 4.1 x 10^{-15} eV·s, 1 eV = 1.60 x 10^{-19} J, c = 3.0 x 10^{8} m/s)

Scoring Scheme

Answer

E = 8.0 eV   1 eV = 1.60 x 10^{-19} J

✓ c = 3.0 x 10^{8} m/s

✓ $p = \frac{E}{c}$

✓ $= \frac{(8.0 \text{ eV})\ (1.60 \times 10^{-19} \text{ J/ev})}{(3.0 \times 10^{8} \text{ m/s})}$

$= 4.267 \times 10^{-27}$ kg·m/s

✓ ✓ $= 4.3 \times 10^{-27}$ kg·m/s

✓ The momentum of the photon is 4.3 x 10^{-27} kg·m/s

MATTER WAVES

1

S17C
IV.7.b

123

A8
F1
A3

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Determine the de Broglie wavelength of an electron having 5.0×10^{-19} J of kinetic energy. (Assume that the mass of the electron is 9.1×10^{-31} kg and that the value of Planck's constant is 6.63×10^{-34} J·s).

Scoring Scheme	Answer
✓	$E_k = 5.0 \times 10^{-19}$ J $h = 6.63 \times 10^{-34}$ J·s
	$m = 9.1 \times 10^{-31}$ kg
✓	$E_k = \frac{1}{2} mv^2$
✓	$5.0 \times 10^{-19}\ \text{J} = \frac{1}{2}(1.1 \times 10^{-31}\ \text{kg})v^2$
	$v^2 = \dfrac{2 \times 5.0 \times 10^{-19}\ \text{J}}{9.1 \times 10^{-31}\ \text{kg}}$
	$= 1.10 \times 10^{12}\ \text{m}^2/\text{s}^2$
✓ ✓	$v = 1.05 \times 10^{6}$ m/s
✓	$p = mv$
✓	$\lambda = \dfrac{h}{p}$
✓	$= \dfrac{h}{mv}$
✓	$= \dfrac{6.63 \times 10^{-34}\ \text{J·s}}{(9.1 \times 10^{-31}\ \text{kg})(1.05 \times 10^{6}\ \text{m/s})}$
✓ ✓	$= 6.9 \times 10^{-10}$ m
✓	The de Broglie wavelength of the electron is 6.9×10^{-10} m.

2

S17C
IV.7.b

123
120

A8
F1
A3

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A particle has a de Broglie wavelength of 8.0×10^{-10} m and a kinetic energy of 5.0×10^{-35} J.

Determine the approximate value of the mass of the particle. (Assume that the value of Planck's constant is 6.6×10^{-34} J·s).

Scoring Scheme — Answer

✓ $\lambda = 8.0 \times 10^{-10}$ m $\qquad E_k = 5.0 \times 10^{-35}$ J

$h = 6.6 \times 10^{-34}$ J·s

✓ $$\lambda = \frac{h}{p} \qquad E_k = \frac{p^2}{2\,m}$$

$$\lambda = \frac{h}{\sqrt{2\,mE_k}}$$

✓ $$m = \frac{h^2}{2\,E_k\lambda^2}$$

✓ $$= \frac{(6.6 \times 10^{-34}\ \mathrm{J\cdot s})^2}{2\,(5.0 \times 10^{-35}\ \mathrm{J})\,(8.0 \times 10^{-10}\ \mathrm{m})^2}$$

$$= \frac{(6.6)^2}{2\,(5.0)\,(8.0)^2} \times \frac{10^{-68}}{10^{-35} \times 10^{-20}} \quad \frac{\mathrm{J^2 \cdot s^2}}{\mathrm{J \cdot m^2}}$$

$$= \frac{1}{10}\left(\frac{6.6}{8}\right)^2 \times 10^{-13}\ \mathrm{kg}$$

$$= (0.825)^2 \times 10^{-14}\ \mathrm{kg}$$

$$= 0.6806 \times 10^{-14}\ \mathrm{kg}$$

✓ ✓ $$= 6.8 \times 10^{-15}\ \mathrm{kg}$$

✓ The approximate value for the mass of the particle is 6.8×10^{-15} kg.

3

S17C
IV.7.b

123

F1
A8

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Calculate the de Broglie wavelength of a 20 g bullet travelling at a speed of 1500 m/s.
(h = 6.62×10^{-34} J·s)

Scoring Scheme	Answer
√	$m = 20\text{ g} = 2.0 \times 10^{-2}\text{ kg}$ $h = 6.62 \times 10^{-34}\text{ J·s}$
√	$v = 1.50 \times 10^{3}\text{ m/s}$
√	$\lambda = \dfrac{h}{mv}$
√	$= \dfrac{6.62 \times 10^{-34}\text{ J·s}}{(2.0 \times 10^{-2}\text{ kg})(1.50 \times 10^{3}\text{ m/s})}$
√ √	$= 2.2 \times 10^{-35}\text{ m}$
√	The de Broglie wavelength of the bullet is 2.2×10^{-35} m.

THE ATOM

ENERGY LEVELS

1 An atom undergoes an energy transition from an energy level of 9.1 eV to an energy level of 6.7 eV.

S17C
IV.6.c Given $h = 4.1 \times 10^{-15}$ eV·s, determine the wavelength of a photon emitted by this atom. ($c = 3.0 \times 10^{8}$ m/s)

129
116

A8
F1
A3

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Scoring Scheme

Answer

✓ $E_2 = 9.1$ eV $\quad h = 4.1 \times 10^{-15}$ eV·s

$E_1 = 6.7$ eV $\quad c = 3.0 \times 10^{8}$ m/s

$E = hf$

$= \frac{hc}{\lambda}$

✓ $\lambda = \frac{hc}{E}$

✓ $= \frac{hc}{E_2 - E_1}$

✓ $= \frac{(4.1 \times 10^{-15}\ \text{eV·s})(3.0 \times 10^{8}\ \text{m/s})}{9.1\ \text{eV} - 6.7\ \text{eV}}$

$= \frac{12.3 \times 10^{-7}\ \text{eV·m}}{2.4\ \text{eV}}$

$= 5.125 \times 10^{-7}$ m

✓ ✓ $= 5.1 \times 10^{-7}$ m

✓ The wavelength of the photon emitted is 5.1×10^{-7} m.

2

S17C
IV.6.c

132

F1
A8
A3

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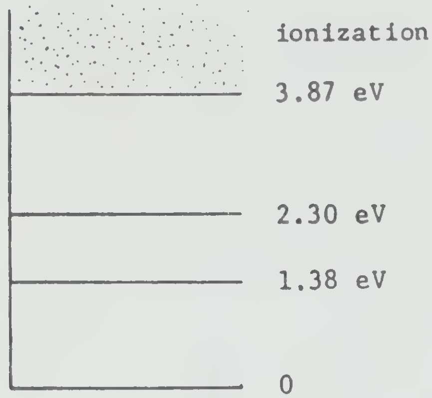
The energy level diagram for cesium is shown below. (h = 4.1 x 10^{-15} eV·s, c = 3.0 x 10^{8} m/s)



Determine the longest wavelength of electromagnetic radiation that could be absorbed by a cesium atom in the ground state.

Scoring Scheme | Answer

$h = 4.1 \times 10^{-15}$ eV·s $\qquad c = 3.0 \times 10^{8}$ m/s

✓ $\lambda = \frac{hc}{E}$

✓ $= \frac{hc}{E_1 - E_0}$

✓ $= \frac{(4.1 \times 10^{-15}\ \text{eV·s})\ (3.0 \times 10^{8}\ \text{m/s})}{1.38\ \text{eV} - 0}$

$= \frac{12.3}{1.38} \times 10^{-7}\ \frac{\text{eV·m}}{\text{eV}}$

✓ ✓ $= 8.9 \times 10^{-7}$ m

✓ The longest wavelength that could be absorbed by this atom from ground state is 8.9 x 10^{-7} m.

S O U N D

MUSIC

1

S17A
II.2.a

157
156
S 155

A11

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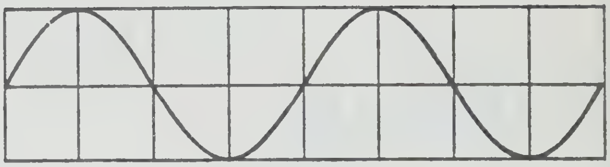
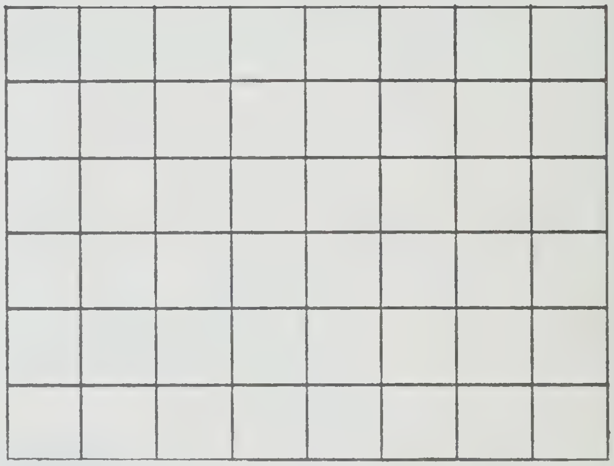
The oscilloscope tracing produced by a pure tone is drawn in space A. Assume that no adjustments are made to the oscilloscope.

A



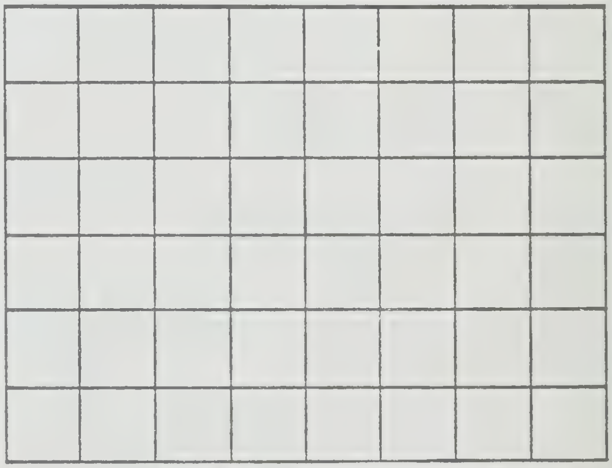
In space B draw the tracing that could result if a louder sound of the same pitch shown in A were displayed on the oscilloscope.

B



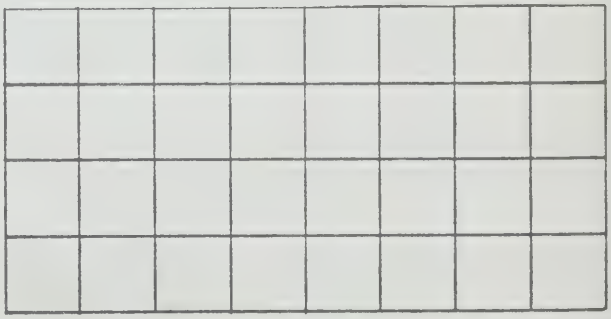
In space C draw the tracing that could result if a sound of the same amplitude as that shown in A, but of higher frequency than shown in A, were displayed on the oscilloscope.

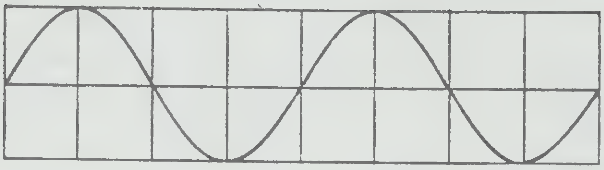
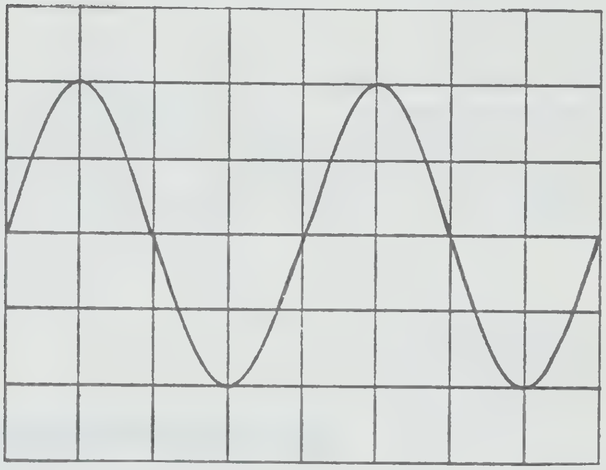
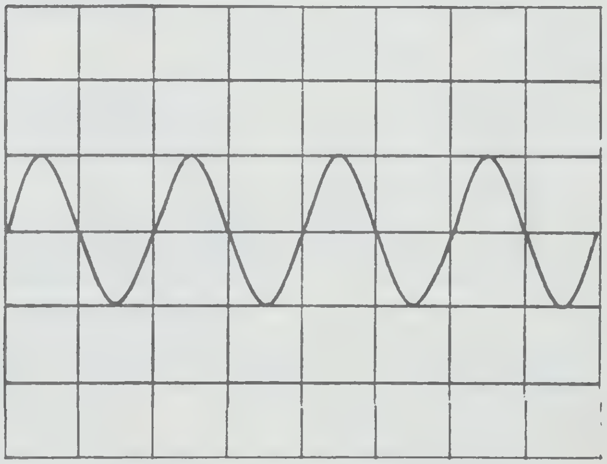
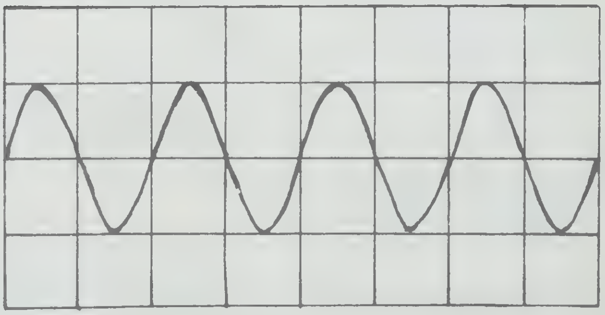
C



In space D draw the tracing that could result if the second harmonic of the pure tone shown in A, but having the same amplitude shown in A, were displayed on the oscilloscope.

D



Scoring Scheme	Answer		
		A (Given)	
√ √	same pitch throughout large amplitude	B	
√ √	same amplitude greater frequency (shorter λ)	C	
√ √	same amplitude half the wavelength	D	

ELECTROMAGNETISM

APPLICATIONS

1

S17A
III.3.p

217
216
215
104

B4
F1
A2

Column I lists a number of quantities to be measured. Column II lists a number of instruments available for making measurements.

In the space provided before each quantity to be measured in Column I, write the letter corresponding to the instrument from Column II which is most suitable for that measurement. A particular instrument from the list may be used once, more than once, or not at all.

** - *** Answer & Scoring Scheme		I Quantity to be measured	II Measuring Instruments and their ranges
√ (A)	______	1. The potential difference across a flashlight battery	(A) DC voltmeter (0-10 V)
√ (F)	______	2. The current drawn by a 1 Ω resistor connected to a flashlight battery	(B) DC voltmeter (0-200 V)
√ (C)	______	3. The potential difference across the secondary coil of a transformer when the primary is connected to a standard home outlet and has 20 times as many turns as the secondary	(C) AC voltmeter (0-10 V)
√ (H)	______	4. The current drawn by a 60 W light bulb connected to a standard household outlet	(D) AC voltmeter (0-200 V)
√ (I)	______	5. The current induced in a coil of 100 turns by a bar magnet thrust into the coil	(E) DC ammeter (0-500 mA)
√ (E)	______	6. The current drawn by a 100 Ω resistor connected to a flashlight battery	(F) DC ammeter (0-5 A)
			(G) AC ammeter (0-100 mA)
			(H) AC ammeter (0-5 A)
			(I) Galvanometer (0-10 mA)

RAY

OR

GEOMETRIC OPTICS

REFLECTION

1 Consider the following diagram showing the reflection of an object in a concave mirror.

S17A
II.1.a

270

A2

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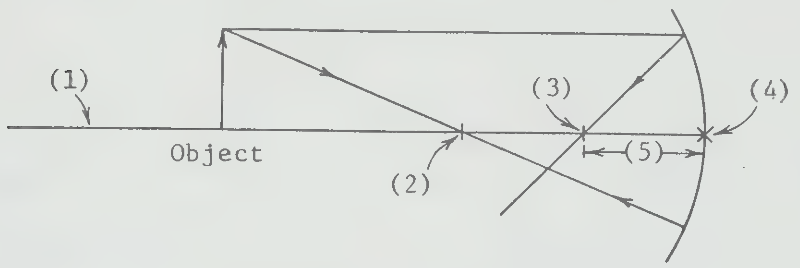
*



State the name corresponding to each number in the diagram.

(1) ____________________

(2) ____________________

(3) ____________________

(4) ____________________

(5) ____________________

Scoring Scheme	Answer
√	(1) principal axis
√	(2) centre of curvature
√	(3) principal focus
√	(4) vertex
√	(5) focal length

2

S17A
II.3.a

274

A7
A5
A8

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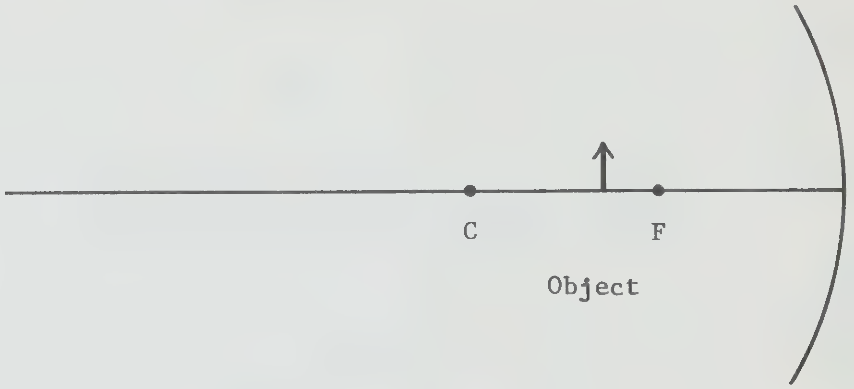
**

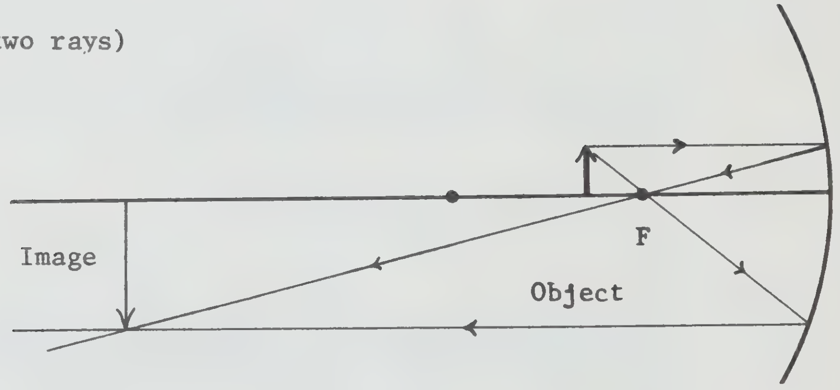
For the position of the object shown, locate the image produced by the concave mirror by drawing two appropriate rays.



Scoring Scheme

Answer

(Any two rays)



✓ ray 1 before reflection

✓ ray 1 after reflection

✓ ray 2 before reflection

✓ ray 2 after reflection

✓ arrowheads shown

✓ location of image

✓ attitude of image

3

S17A
II.3.a

274

A7
A8
A5

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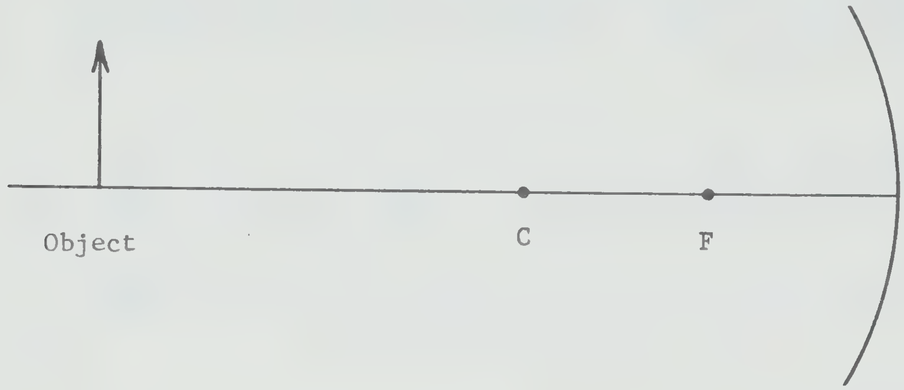
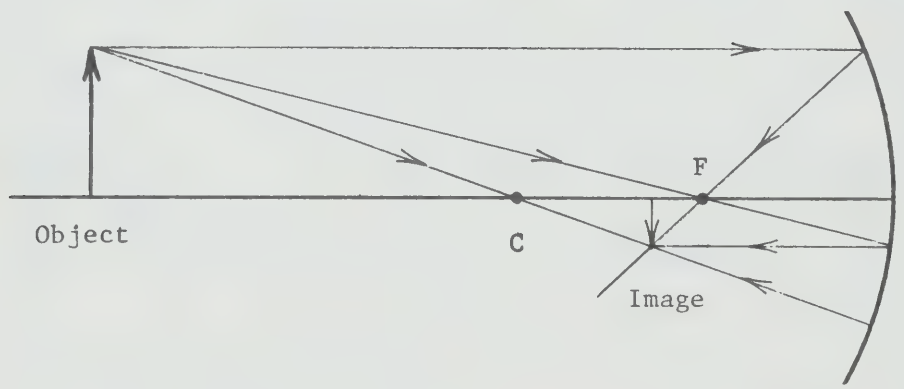
For the position of the object shown, locate the image produced by the concave mirror by drawing any two appropriate rays.



Scoring Scheme

Answer

(Any two rays)



✓ ray 1 before reflection

✓ ray 1 after reflection

✓ ray 2 before reflection

✓ ray 2 after reflection

✓ arrowheads shown

✓ location of image

✓ attitude of image

4

S17A
II.3.a

274

A7
A8
A5

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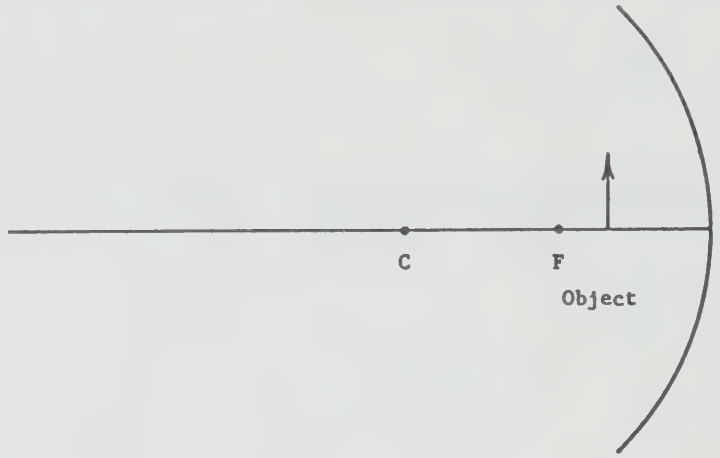
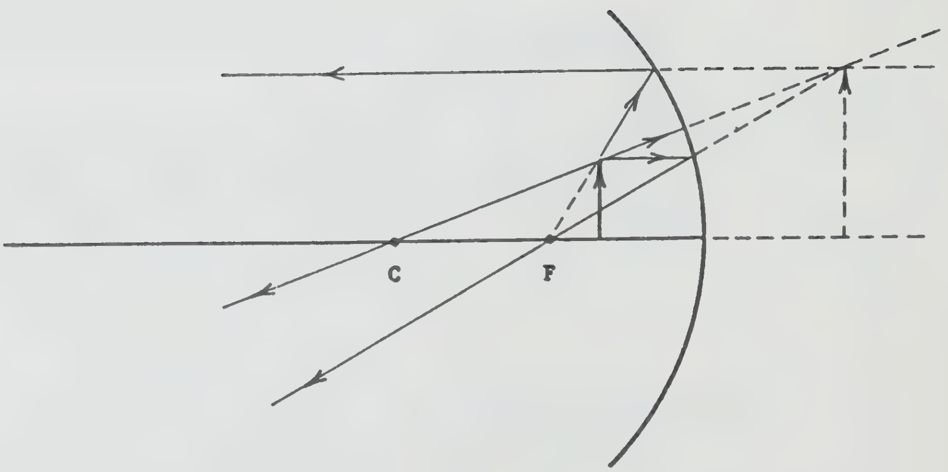
*
**

For the position of the object shown, locate the image produced by the concave mirror by drawing any two appropriate rays.



Scoring Scheme

Answer



✓	ray 1 before reflection
✓	ray 1 after reflection
✓	ray 1 extended back
✓	ray 2 before reflection
✓	ray 2 after reflection
✓	ray 2 extended back
✓	arrowheads shown
✓	location of image
✓	attitude of image
✓	image dotted

5 An object 2.0 cm high is located 12 cm from a converging (concave) mirror of focal length 4.0 cm.

S17A
II.3.a
275
F1
A2
A11
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**

(a) Make an accurate, labelled, full size diagram showing the mirror, the focal point F, and the location, attitude and size of the object.

(b) Use rays to locate the image.

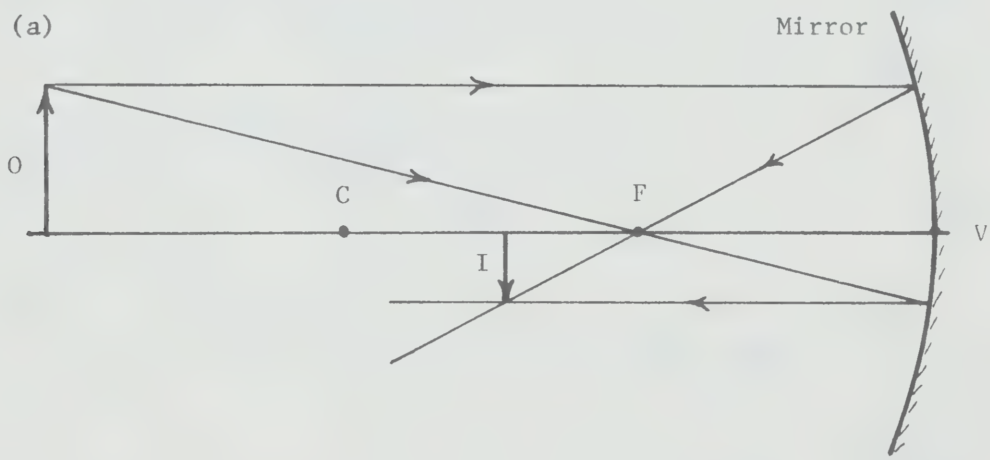
(c) From the diagram specify the position of the image from the vertex in cm, and the size of the image in cm.

(d) State the kind and the attitude of the image.

Scoring Scheme

Answer

(a)



Scoring	Answer
	Let 1 cm represent 1 cm
√	object height = 2 cm
√	object location is 12 cm from vertex
√	focal length = 4 cm
√	radius of curvature of mirror = 8 cm
	(b) (See above)
√ √ √ √	Construction of 2 rays
√ √	Drawing of image
√ √	(c) Position - about 6.0 cm from vertex
√ √	Size - 1 cm
√	(d) Attitude - inverted
√	Kind - real

REFRACTION

1

S17A
II.3.a
S17C
II.1.b

S 278

A2

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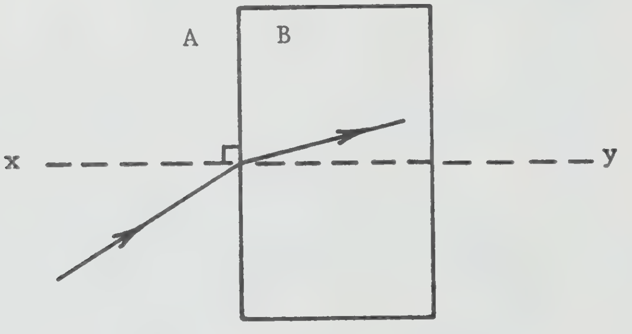
The diagram represents a ray of light travelling from one transparent material A to another transparent material B.



The name given to the line xy is the __________.

Scoring Scheme	Answer
✓	normal

2

S17A
II.3.a
S17C
II.1.b

S 278

A2
A11

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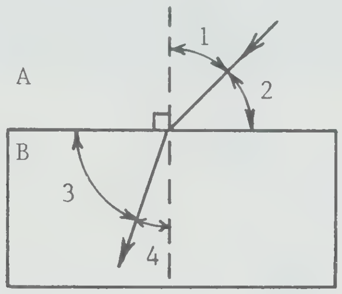
*

The diagram shows a ray of light travelling from one transparent material A to another transparent material B.



Which number in the diagram represents the

(a) angle of incidence? __________

(b) angle of refraction? __________

Scoring Scheme	Answer
✓	(a) 1
✓	(b) 4

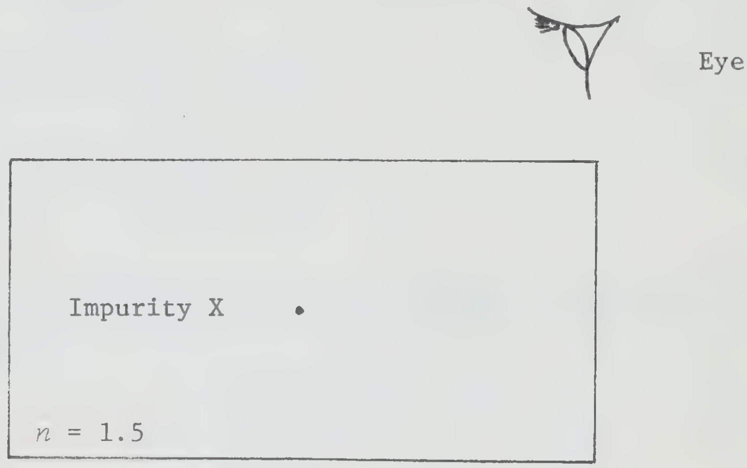
3

S17A
II.3.a
S17C
II.1.b

S 280
S 60

**
*
**

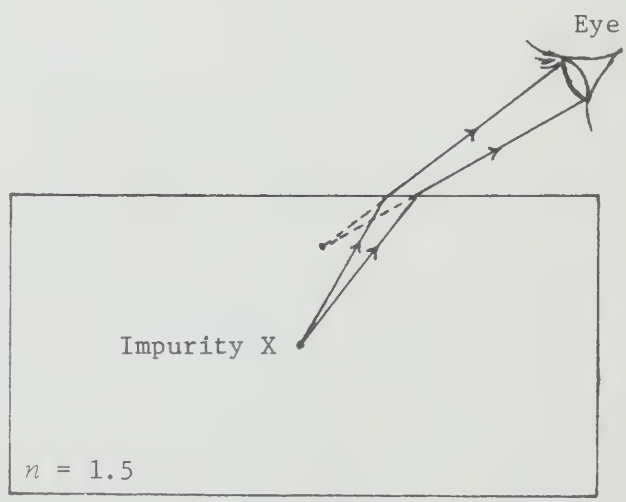
The small point labelled X in the diagram represents an impurity contained inside a clear rectangular block of glass. A student views the impurity from the position shown in the diagram below. Assume that the student can see the impurity.



(a) Draw two rays, one to the top and one to the bottom of the eye, to show the approximate path the light travels from the impurity to the eye.

(b) Use the two rays to show where the impurity appears to be from the student's point of view.

Scoring Scheme	Answer
√	(a) ray 1 in glass
√	ray 1 in air
√	$i_1 < R_1$
√	ray 2 in glass
√	ray 2 in air
√	$i_2 < R_2$
√	(b) ray 1 extended back
√	ray 2 extended back
√	extended rays meet at a point above X
√	and closer to the eye



4

S17A
II.3.a
S17C
II.1.b

S 283

B1
A4
A11

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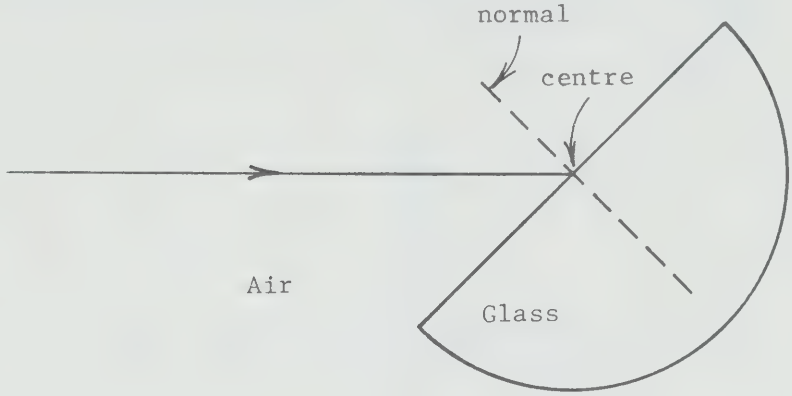
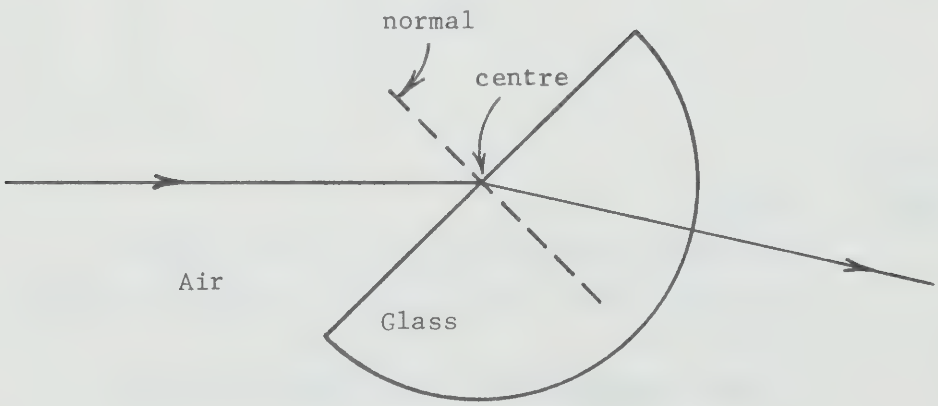
*
*

A ray of light strikes the surface of a semicircular piece of glass as shown below.

On the diagram, draw the <u>approximate</u> path taken by the ray as it passes through the glass.



Scoring Scheme	Answer
√	$i > R$
√	continues straight into air
√	shows direction with arrowhead



5

A ray of light AB strikes a convex lens TU as shown in the diagram below.

S17A
II.3.b
S17C
II.1.b

285
271
261

B3
F1

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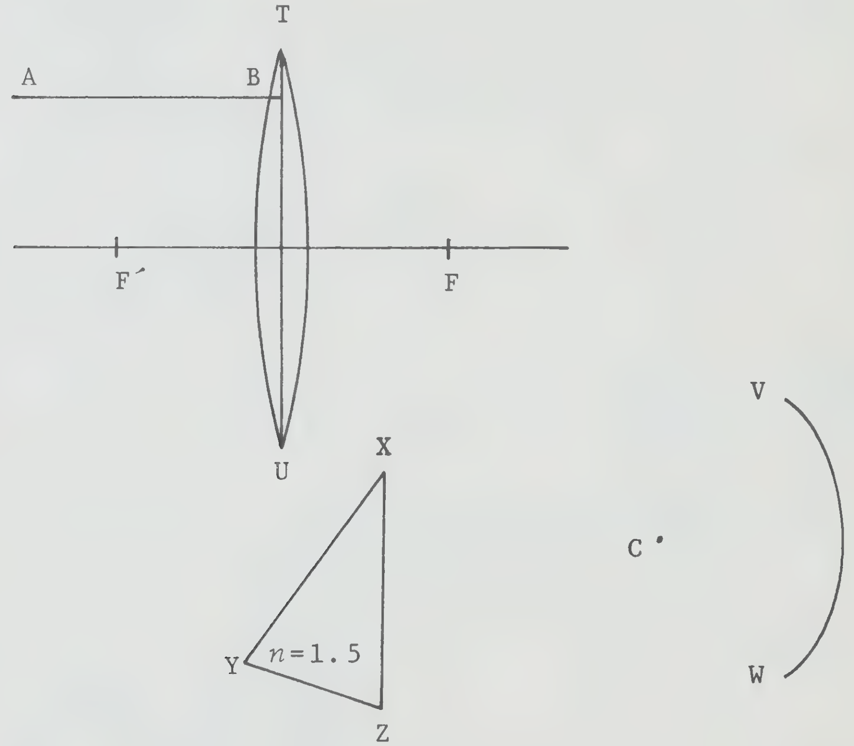
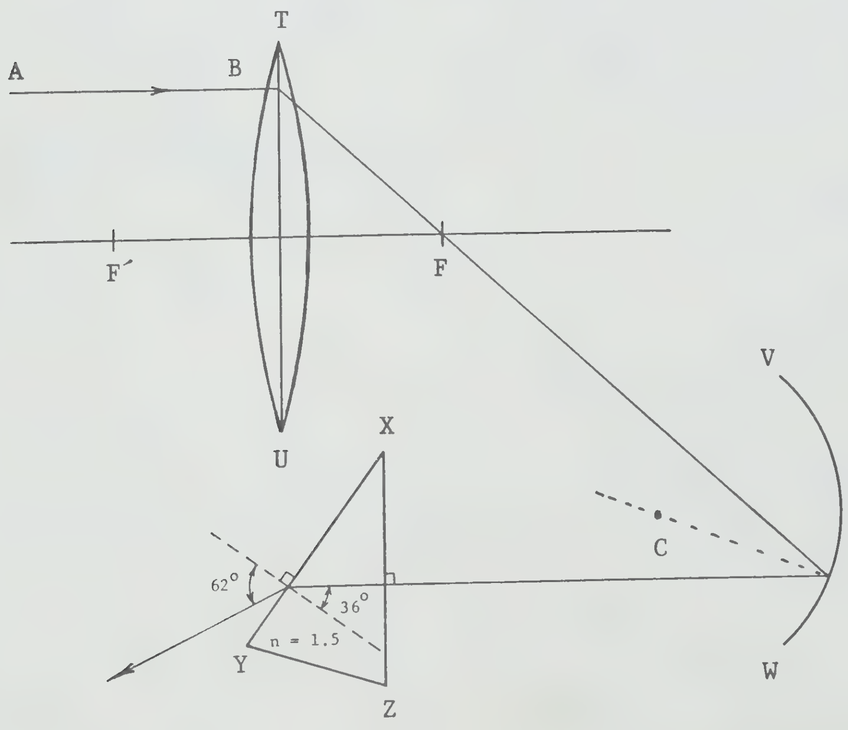
By making the appropriate measurements and calculations, determine the path of the ray as it passes through the lens, reflects from the mirror VW and finally passes through the triangular prism XYZ. NOTE: C is the centre of curvature of the mirror.



Scoring Scheme	Answer
✓	refracted ray drawn through F to hit mirror
✓	line drawn from C to point of incidence on mirror
✓	$i = r = 42°$
✓	reflected ray incident on surface XZ at 90°
✓	no refraction at surface XZ
✓	normal drawn at point of incidence of surface XY
✓	$i = 36°$

Scoring Scheme	Answer
√	$n_g \sin \theta_g = n_a \sin \theta_a$
√	$\sin \theta_a = \frac{n_g}{n_a} \sin \theta_g$
√	$= \frac{1.5}{1.0} \sin 36°$
√	$= \frac{1.5}{1.0} \times 0.5878$
√	$= 0.8816$
√	$\sin \theta_a = 62°$
√	$R = 62°$



6

S17A
II.3.a
S17C
II.1.b

286

A2
A11

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With the aid of a labelled diagram, explain what is meant by the following statement: "The critical angle for glass in air is 42°."

Scoring Scheme

√ The critical angle is that angle of incidence in the medium with a higher refractive index which yields an angle of refraction in the medium with the lower refractive index of 90°.

√ Light must be travelling from glass toward air at i = 42° to produce R = 90°.

Diagram

√ normal labelled

√ air labelled

√ glass labelled

√ i = 42° labelled in glass

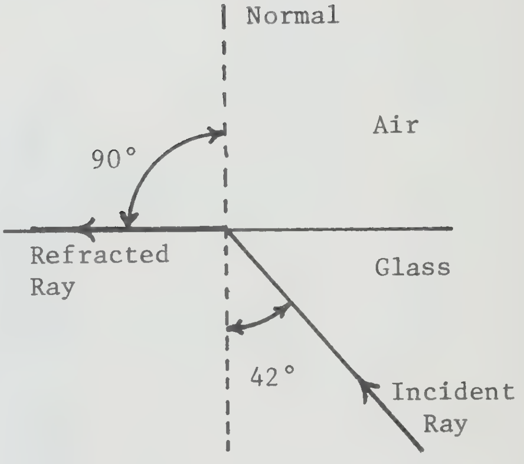
√ R = 90° labelled in air

√ incident ray labelled

√ refracted ray labelled

√ arrowheads shown

Answer



7 Diamond has an absolute refractive index of 2.4. Calculate the value of the critical angle for diamond.

S17A
II.3.a
S17C
II.1.a

287
82

F1
A8

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Scoring Scheme	Answer
√	$n_{diamond} = 2.4$
√	The angle of refraction is 90° when the angle of incidence equals the critical angle.
	$n_1 \sin \theta_1 = n_2 \sin \theta_2$
√	$n_{diamond} \sin \theta_i = n_{air} \sin \theta_R$
√	$2.4 \sin \theta_{crit} = 1.0 \sin 90°$
√	$\sin \theta_{crit} = \frac{1.0}{2.4}$
√	$= 0.42$
√	$\theta_{crit} = 25°$
√	The critical angle for diamond is 25°.

8 Give one practical application of the total internal reflection of light.

S17A
II.3.a
S17C
II.1.b

290
286

F1
A2

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-
*

Scoring Scheme	Answer
√	Total internal reflection is used to change the direction of light in periscopes, prisms, binoculars and fibrescopes.

9

S17A
II.3.a
S17C
II.1.b

291
285

B3
F1

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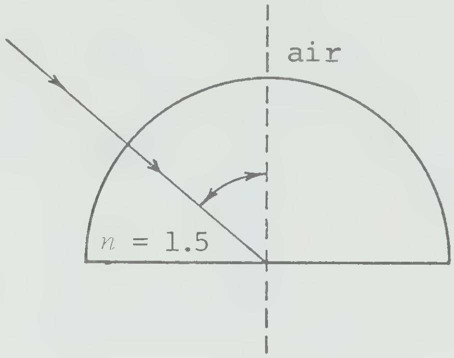
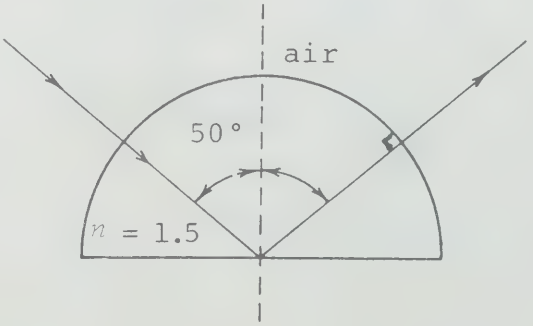
A ray of light travelling in an optical dish is incident on the interface between the dish and air as shown.



By making appropriate measurements and calculations determine and accurately draw on the diagram the path taken by the ray of light after it leaves the interface. Label the size of all relevant angles.

Scoring Scheme	Answer
✓ n_{air}	$n_{air} = 1.0$ $\quad n_{dish} = 1.5$
✓ measurement	$\theta_d = 50°$
✓ value of $\sin\theta_d$	$\sin\theta_d = 0.766$
✓ relationship	$n_a \sin\theta_a = n_d \sin\theta_d$
✓ substitution	$\sin\theta_a = \dfrac{(1.5)\ (0.766)}{1.0}$
✓ solution	$= 1.1$
✓ interpretation	Refraction is not possible since $\sin\theta_a > 1$.
✓ statement of reflection shown on diagram	∴ the incident ray undergoes total internal reflection.
✓ drawing r	angle of reflection $r = 50°$
✓ passage of reflected ray in dish	
✓ passage of reflected ray in air	



10

S17A
II.3.a
S17C
II.1.b

291
285

B3
F1

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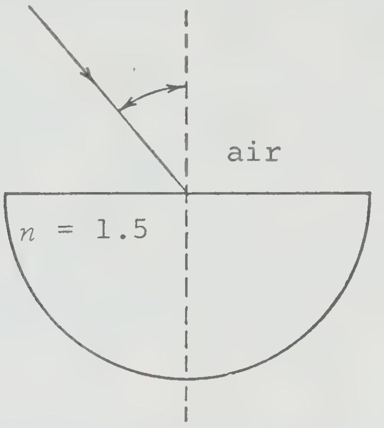
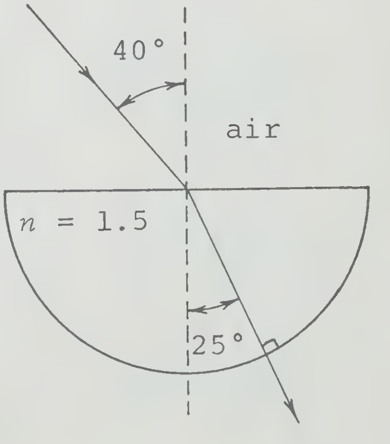
A ray of light is incident on the interface between air and an optical dish as shown.



By making appropriate measurements and calculations determine and accurately draw on the diagram the path taken by the refracted ray of light after it leaves the interface. Label the size of all relevant angles.

Scoring Scheme	Answer
✓ n_{air}	$n_{air} = 1.0$ $\quad n_d = 1.5$
✓ measurement of θ_a	$\theta_a = 40°$
✓ relationship	$n_a \sin\theta_a = n_d \sin\theta_d$
✓ substitution	$1.0 \sin 40° = 1.5 \sin\theta_d$
✓ rearrangement	$\sin\theta_d = \dfrac{1.0 \sin 40°}{1.5}$
✓ value of sin θ_a	$= \dfrac{(1.0)\ (0.6428)}{1.5}$
✓ solution	$= 0.4285$
✓ angle	$\theta_d \simeq 25°$
✓ relationship	$R = \theta_d$
✓ drawing R	$R = 25°$
✓ passage of refracted ray in dish	
✓ passage of refracted ray outside dish	



11

S17A
II.3.a
S17C
II.1.b

291
285

B3
F1

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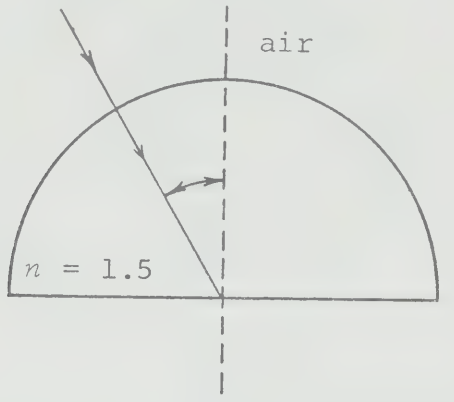
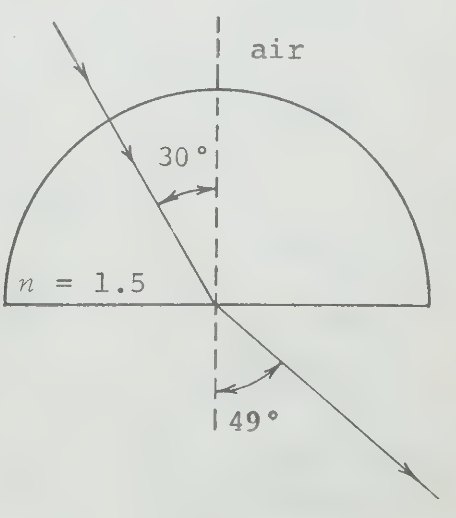
A ray of light travelling in an optical dish is incident on the interface between the dish and air as shown.



By making appropriate measurements and calculations determine and accurately draw on the diagram the path taken by the refracted ray of light after it leaves the interface. Label the size of all relevant angles.

Scoring Scheme	Answer
√ n_{air}	$n_{air} = 1.0$ $\quad n_d = 1.5$
√ measurement of θ_d	$\theta_{dish} = 30°$
√ relationship	$n_d \sin \theta_d = n_a \sin \theta_a$
√ substitution	$1.5 \sin 30° = 1.0 \sin \theta_a$
	$\sin \theta_a = \dfrac{1.5 \sin 30°}{1.0}$
√ solution	$= \dfrac{(1.5)\ (0.5)}{1.0}$
	$= 0.75$
√ angle	$\theta_a \simeq 49°$
relationship	$\theta_a = R$
√ drawing refracted ray	$R = 49°$
√ labelling R	



12

S17A
II.3.a
S1/C
II.1.b

291
285

B3
F1

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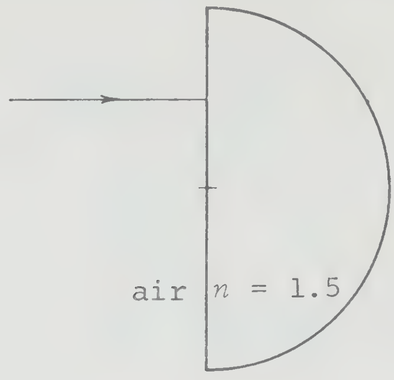
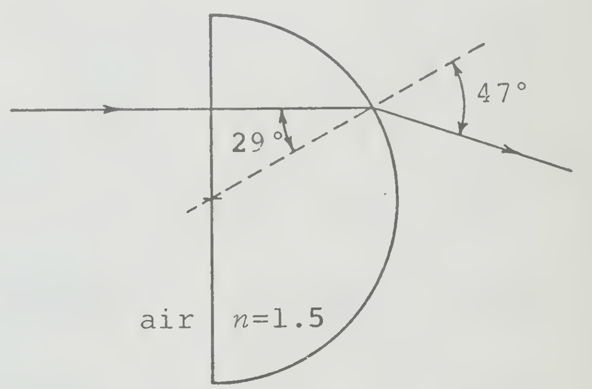
A ray of light is incident on the interface between air and an optical dish as shown.



By making appropriate measurements and calculations determine and accurately draw on the diagram the path taken by the ray of light in the optical dish <u>and</u> in air. Label the size of all relevant angles.



Scoring Scheme	Answer
✓	$n_{air} = 1.0$
✓ extending ray to curved interface	$n_d = 1.5$
✓ drawing the normal	
✓ measurement	$\theta_d = 29°$
✓ value of sin	$\sin 29° = 0.4848$
✓ relationship	$n_d \sin \theta_d = n_a \sin \theta_a$
✓ substitution	$(1.5)\ (0.4848) = 1.0 \sin \theta_a$
	$\sin \theta_a = \dfrac{(1.5)\ (0.4848)}{1.0}$
✓ solution	$= 0.7272$
✓ angle	$\theta_a \simeq 47°$
✓ relationship	$R = \theta_a$
✓ drawing of normal	$= 47°$
✓ drawing of ray	
✓ labelling of R	

13

S17A
II.3.a
S17C
II.1.b

291
285

B3
F1

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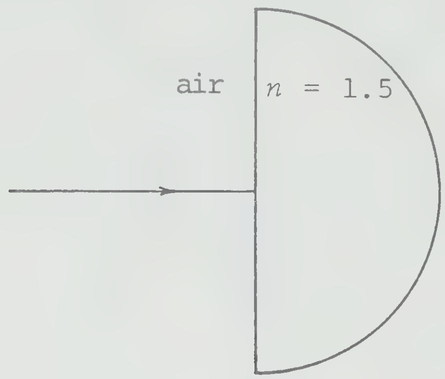
A ray of light is incident on the interface between air and an optical dish as shown.



By making appropriate measurements and/or calculations determine and accurately draw on the diagram the path taken by the ray of light in the optical dish and in the air. Label the size of all relevant angles.

Scoring Scheme

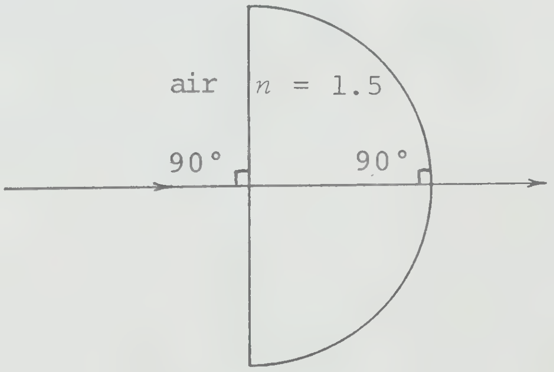
Air to Dish

i = 0° or angle between incident ray and interface = 90°
✓
R = 0° or angle between ray in dish and interface = 90°
✓
ray drawn straight; no change in direction

Dish to Air

i = 0° or angle between incident ray and interface = 90°
✓
R = 0° or angle between emergent ray and interface = 90°
✓
ray drawn straight; no change in direction

Answer



14

S17A
II.3.a

291

F1
A8
A2

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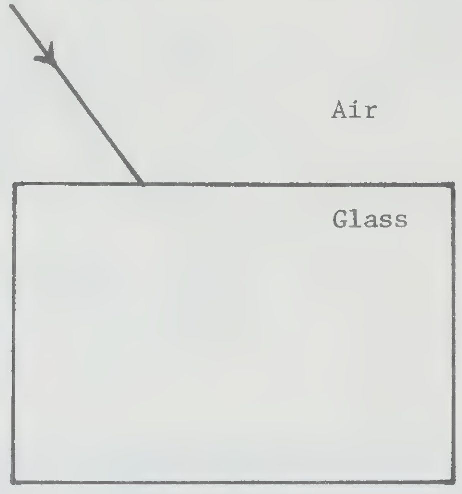
A ray of light strikes the surface of a rectangular piece of glass as shown below.



(a) On the diagram, draw the approximate path taken by the ray as it passes through the glass.

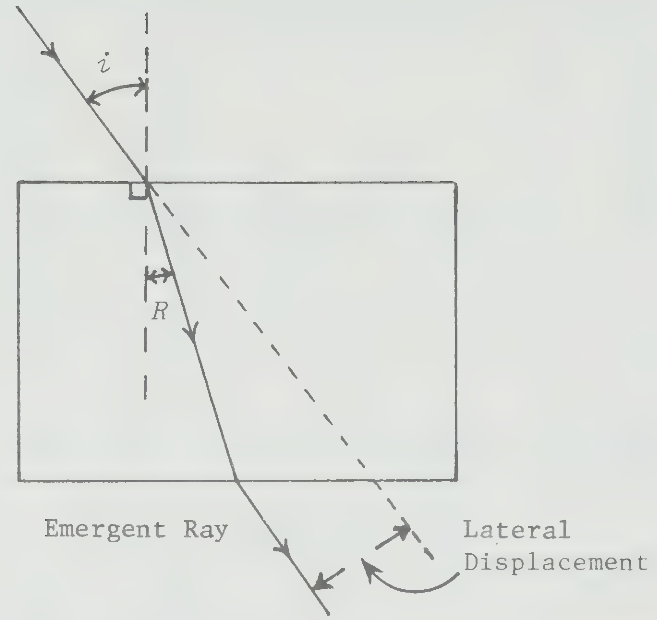
(b) Label the angle of incidence, the angle of refraction in the glass, and the emergent ray.

(c) Label the lateral displacement.

(d) As the angle of incidence increases, what happens to the lateral displacement?

(e) As the thickness of the glass increases, what happens to the lateral displacement?

Scoring Scheme	Answer
	(a)
√ $i > R$	
√ emergent ray parallel to incident ray	
	(b)
√ normal	
√ i	
√ R	
√ emergent ray	
	(c)
√ incident ray extended	
√ lateral displacement	



√ √	(d) As i increases, the lateral displacement increases.
√ √	(e) As the thickness of the glass increases, the lateral displacement increases.

15

S17A
II.3.b

296

A7
A8
A5

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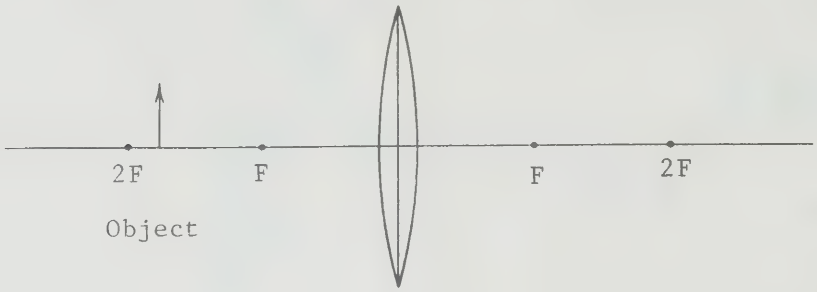
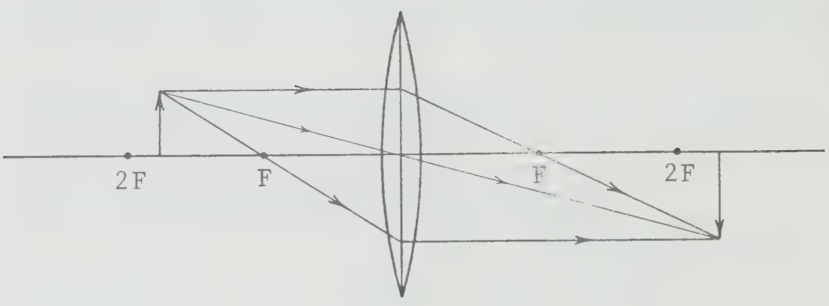
For the position of the object shown, locate and draw the image produced by the convex (converging) lens by drawing any two appropriate rays.



Scoring Scheme

Answer

(Any two rays)



√	ray 1 before lens
√	ray 1 after lens
√	ray 2 before lens
√	ray 2 after lens
√	arrowheads
√	image location
√	image attitude

16

S17A
II.3.b

296

A7
A8
A5

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*
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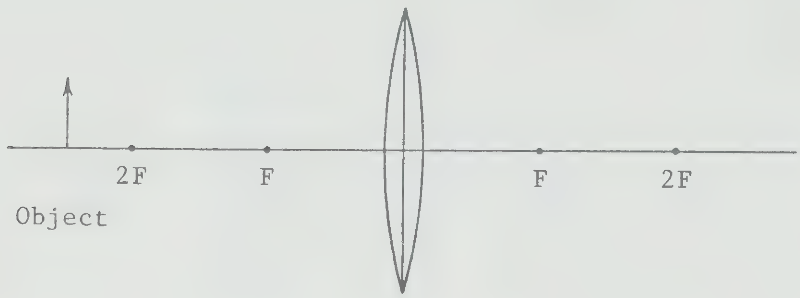
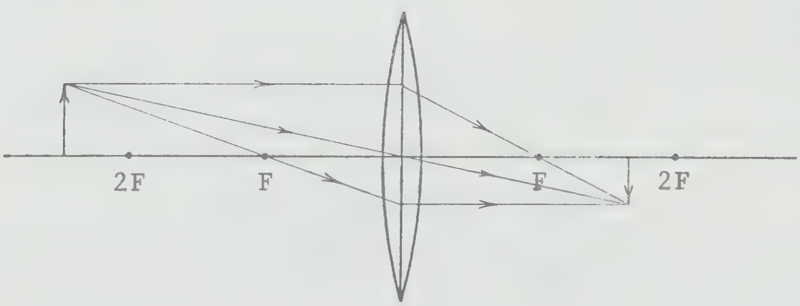
For the position of the object shown, locate and draw the image produced by the convex (converging) lens by drawing any two appropriate rays.



Scoring Scheme

Answer

(Any two rays)



✓ ray 1 before lens
✓ ray 1 after lens
✓ ray 2 before lens
✓ ray 2 after lens
✓ arrowheads
✓ location of image
✓ attitude of image

17 (a) For the position of the object shown, locate and draw the image produced by the concave (diverging) lens by drawing any two appropriate rays.

S17A
II.3.b

297
296

A7
A8
A5

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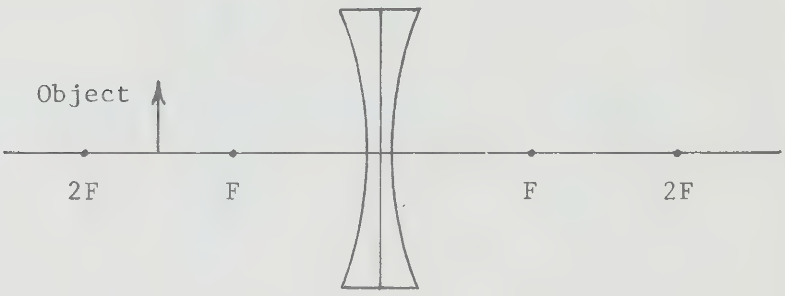
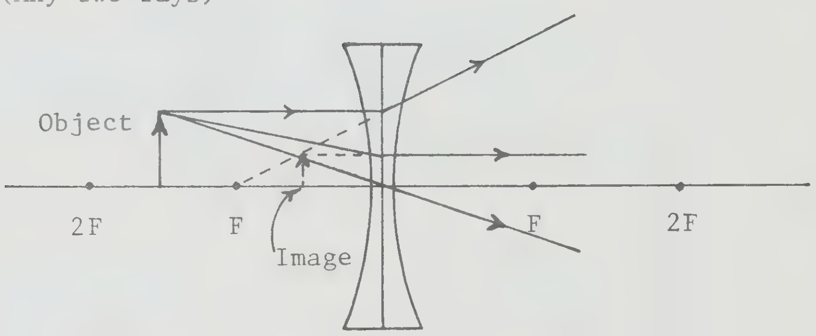


(b) State three characteristics of the image.

Scoring Scheme

Answer

(a) (Any two rays)



√ √	ray 1
√ √	ray 2
√	arrowheads
√ √	projecting two rays back
√	erect image
√	correct location of image
√	(b) erect
√	smaller
√	virtual

18

S17A
II.3.b

297
296

A7
A8
A5

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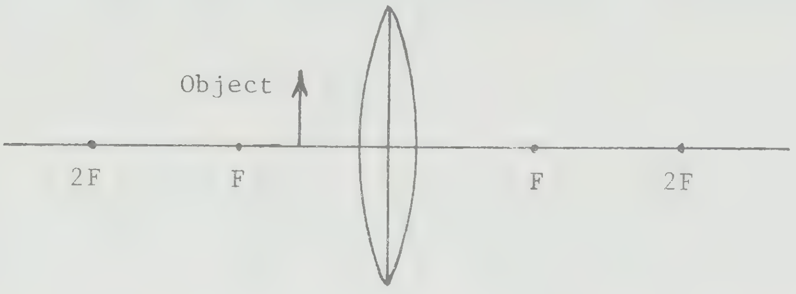
(a) For the position of the object shown, locate and draw the image produced by the convex (converging) lens by drawing two appropriate rays.

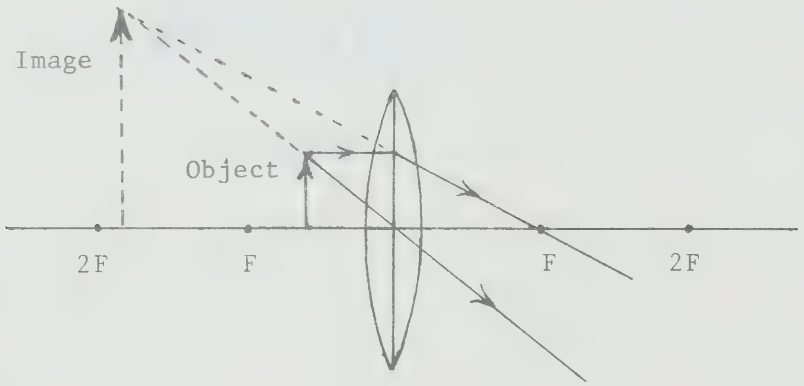


(b) State three characteristics of the image.

Scoring Scheme

Answer

(a)



√ √ parallel ray

√ √ centre ray

√ arrowheads

√ correct attitude

√ dotted lines shown

√ correct position

√ (b) erect

√ larger

√ virtual

COLOUR

THE SPECTRUM

1

S17A
II.3.a

314
S 291

F1
A8
A2

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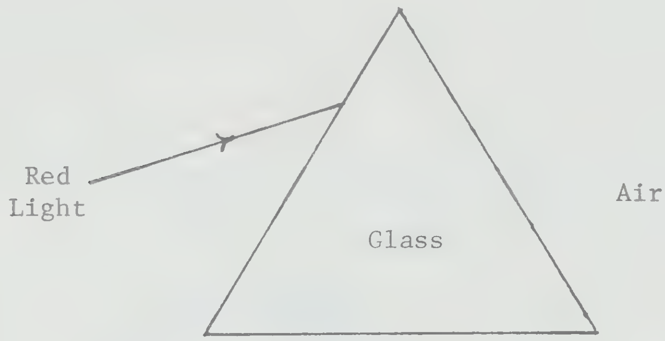
*
**

A ray of red light strikes the surface of a triangular piece of glass as shown below.

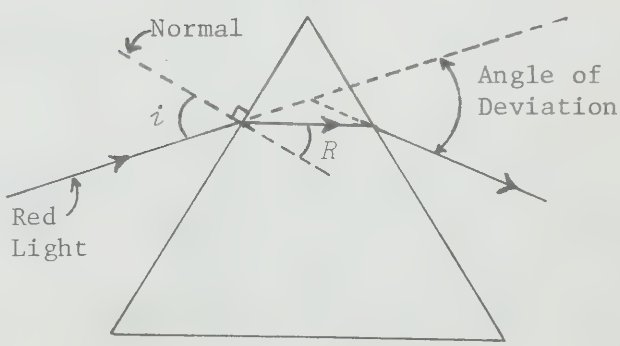


(a) On the diagram, draw the approximate path taken by the ray as it passes through the glass.

(b) Label the angle of incidence, the angle of refraction in the glass, and the angle of deviation.

(c) Briefly describe one application of a triangular prism.

Scoring Scheme	Answer
	(a and b)
✓	construction of normal
✓	angle of incidence
✓	refracted ray
✓	angle of refraction
✓	emergent ray
✓	incident ray extended
✓	angle of deviation
✓ ✓ ✓	(c) separating white light into its colours (dispersion)



COLOUR VISION

1

S17A
II.3.c

328

A2

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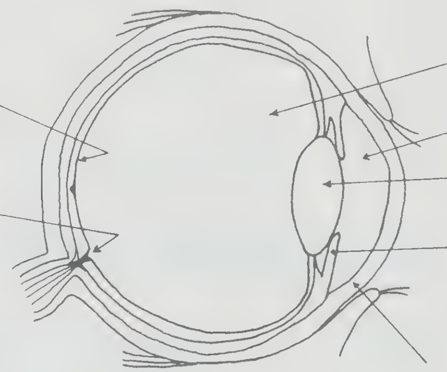
*
*

The following diagram of the human eye has 7 parts marked with arrows and letters.



The names of five parts of the eye are listed below. In the space before each name, write the letter corresponding to the correct part.

Answer	Scoring Scheme		
E	√	________	retina
C	√	________	aqueous humour
B	√	________	lens
G	√	________	cornea
A	√	________	iris

FLUIDS

FLUIDS AT REST

1

340
341

F1
A8
A3

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**

A 60 kg person stands on a 5.0 kg horizontal sheet of plywood. The plywood is 1.0 m wide by 2.0 m long. (g = 10 N/kg)

(a) What is the total mass of the person and the plywood?

(b) What is the total force of gravity on the person and the plywood?

(c) What is the surface area of the plywood in contact with the ground?

(d) With the person on the plywood, what pressure does the plywood exert on the ground?

Scoring Scheme | Answer

✓ $m_p = 60$ kg $w = 1.0$ m $g = 10$ N/kg

$m_{pl} = 5.0$ kg $l = 2.0$ m

(a) $m_t = m_p + m_{pl}$

$= 60$ kg + 5.0 kg

✓ ✓ $= 65$ kg

✓ The total mass is 65 kg.

✓ (b) $F_g = mg$

✓ $= 65$ kg x 10 N/kg

$= 650$ N

✓ ✓ $= 6.5 \times 10^2$ N

✓ The total force of gravity is 6.5×10^2 N.

✓ (c) $A = lw$

✓ $= 2.0 \text{ m} \times 1.0 \text{ m}$

✓ ✓ $= 2.0 \text{ m}^2$

✓ The total surface area in contact with the ground is 2.0 m^2.

✓ (d) $P = F/A$

✓ $= \dfrac{6.5 \times 10^2 \text{ N}}{2.0 \text{ m}^2}$

$= 3.25 \times 10^2 \text{ N/m}^2$

✓ ✓ $= 3.3 \times 10^2 \text{ Pa}$

✓ The plywood exerts a pressure of 3.3×10^2 Pa on the ground.

2 A force of 650 N is applied to an area of 0.25 m^2.

Calculate the pressure in kPa.

340
341

F1
A8
A3

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*

Scoring Scheme	Answer	
✓	$F = 650$ N	$A = 0.25$ m^2
✓	$P = \frac{F}{A}$	
✓	$= \frac{650 \text{ N}}{0.25 \text{ m}^2}$	
	$= 2600$ N/m^2	
	$= 2600$ Pa	
✓ ✓	$= 2.6 \times 10^3$ Pa	
✓	$= 2.6$ kPa	
✓	The pressure is 2.6 kPa.	

3 A force acts on an area of 0.50 m^2 producing a pressure of 240 Pa. How large is the force?

340
341

F1
A8
A3

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*

Scoring Scheme	Answer	
✓	$A = 0.50\ m^2$	$P = 240$ Pa
✓	$P = \frac{F}{A}$	
✓	$\therefore F = PA$	
✓	$= 240\ Pa \times 0.50\ m^2$	
	$= 120$ N	
✓ ✓	$= 1.2 \times 10^2$ N	
✓	The force is 1.2×10^2 N.	

4 A force of 5000 N produces a pressure of 50.0 kPa.

S 340
S 341

Calculate the area on which the force acts.

F1
A8
A3

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**

Scoring Scheme	Answer	
√	F = 5000 N	P = 50.0 kPa
√	$P = F/A$	
√	$A = F/P$	
√	$= \dfrac{5000\ \text{N}}{50.0\ \text{kPa}}$	
√	$= \dfrac{5000\ \text{N}}{50.0 \times 10^3\ \text{Pa}}$	
	$= \dfrac{5.000 \times 10^3\ \text{N}}{5.00 \times 10^4\ \text{Pa}}$	
√ √	$= 1.00 \times 10^{-1}\ \text{m}^2$	
√	The force acts on an area of $1.00 \times 10^{-1}\ \text{m}^2$.	

5

S17A
I.2.e
S17C
III.2.a

342

A1
A2
A5

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A rifle and a penny are the same hèight above level ground. A bullet is fired horizontally from the gun at the same time as the penny is dropped.

(a) Neglecting air resistance, compare the times when the bullet and penny hit the ground.

(b) Justify your answer in (a).

Scoring Scheme	Answer
√	(a) The bullet and penny hit the ground at the same time.
√ √	(b) The horizontal motion of the bullet has no effect on its vertical motion.

6 Calculate the force of gravity on an 11 kg turkey. (g = 10 N/kg)

S17A
I.2.e
S17C
III.2.a

342

F1
A8
A2

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*

Scoring Scheme	Answer	
✓	g = 10 N/kg	m = 11 kg
✓	$F_g = mg$	
✓	= 11 kg x 10 N/kg	
✓ ✓	= 110 N	
✓	The force of gravity on the turkey is 1.1×10^2 N.	

7 Find the mass in g of 75 mL of a liquid whose density is 700 kg/m^3.

S 345

F1
A8
A3

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Scoring Scheme	Answer
	$V = 75$ mL
✓	$= 75 \times 10^{-3}$ L
✓	$= 75 \times 10^{-6}\ m^3$
	$D = 700\ kg/m^3$
✓	$m = DV$
✓	$= \left(700\ \frac{kg}{m^3}\right)\left(75 \times 10^{-6}\ m^3\right)$
✓	$= 52\ 500 \times 10^{-6}$ kg
✓ ✓	$= 53 \times 10^{-3}$ kg
✓ ✓	$= 53$ g
✓	The mass of the liquid is 53 g.

8

A piece of metal, 11.2 cm long, 4.5 cm wide and 1.0 mm thick, has a mass of 30.2 g. Find its density in kg/m^3.

S 345

F1
A8
A3

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Scoring Scheme	Answer	
√	l = 11.2 cm	t = 1.0 mm
	w = 4.5 cm	= 0.10 cm
	m = 30.2 g	
√	$V = lwt$	
√	= 11.2 cm x 4.5 cm x 0.10 cm	
√ √	= 5.04 cm^3	
√	$D = m/V$	
√	$= \frac{30.2\ g}{5.04\ cm^3}$	
√ √	= 5.99 g/cm^3	
√ √ √	= $6.0 \times 10^3\ kg/m^3$	
√	The density of the metal is $6.0 \times 10^3\ kg/m^3$.	

9 Find the density in kg/m^3 of a substance whose mass is 148.5 g and whose volume is 30.5 cm^3.

S 345

F1
A8
A3

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Scoring Scheme	Answer	
✓	$m = 148.5$ g	$V = 30.5$ cm^3
✓	$D = m/V$	
✓	$= \dfrac{148.5\ g}{30.5\ cm^3}$	
✓ ✓	$= 4.87\ g/cm^3$	
✓ ✓	$= 4.87 \times 10^3\ kg/m^3$	
✓	The density of the substance is $4.87 \times 10^3\ kg/m^3$.	

10 The density of a substance is $1850\ kg/m^3$.

What volume in cm^3 is occupied by 100 g of the substance?

S 345

F1
A8
A3

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Scoring Scheme	Answer	
	$D = 1850\ kg/m^3$	$m = 100\ g$
✓	$= 1.850\ g/cm^3$	
✓	$V = m/D$	
✓	$= \dfrac{100\ g}{1.850\ g/cm^3}$	
✓ ✓	$= 54.0\ cm^3$	
✓	The substance has a volume of $54.0\ cm^3$.	

11 An 8.0 g cork is floating in water. Find the volume of water, in mL, displaced by the cork.

351 (D_w = 1000 kg/m^3)
345

F1
A8
A3

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Scoring Scheme	Answer
√	$m_c = 8.0$ g $D_w = 1000$ kg/m^3
√	Mass of water displaced = m_c (Principle of Flotation)
√	$m_w = 8.0$ g
√	$V_w = \frac{m_w}{D_w}$
√	$= \frac{8.0 \text{ g}}{1.0 \text{ g/mL}}$
√ √	$= 8.0$ mL
√	The cork displaces 8.0 mL of water.

12 An object floating in alcohol displaces 25 mL of alcohol. The density of alcohol is 800 kg/m^3.

351
345

Determine the mass in g of the object.

F1
A8
A3

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Scoring Scheme	Answer
	$D_a = 800\ kg/m^3$
√	$= 8.00 \times 10^{-1}\ g/mL$
	$V_a = 25\ mL$
√	$m_a = D_a V_a$
√	$= 8.00 \times 10^{-1}\ g/mL \times 25\ mL$
√ √	$= 20\ g$
√	The mass of a floating object = mass of liquid displaced. (Principle of Flotation)
√	The object has a mass of 20 g.

13 An object floats in a liquid with 3/4 of its volume submerged. The density of the object is 460 kg/m^3.

351
345 Find the density of the liquid in kg/m^3.

F1
A8
A3

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Scoring Scheme / Answer

$D_o = 460 \text{ kg/m}^3$

✓ Let the volume of the object be V m^3.

✓ Then the volume of the liquid displaced is $\frac{3}{4}$ V m^3.

✓ According to the Principle of Flotation,

✓ the mass of the floating object = the mass of the displaced liquid

✓ $M = DV$

✓ $\therefore D_l V_l = D_o V_o$

✓ $D_l = D_o \cdot \frac{V_o}{V_l}$

✓ $= 460 \text{ kg/m}^3 \times \frac{V}{3/4 \text{ V}}$

✓ $= 460 \times \frac{4}{3} \text{ kg/m}^3$

✓ ✓ $= 613 \text{ kg/m}^3$

✓ The density of the liquid is 613 kg/m^3.

ENERGY SOURCES

AND

CONSERVATION

ENERGY CONSERVATION

1

Design a procedure to measure the total energy used to wash a load of dishes through a full cycle in a dishwasher. (Do not try out the procedure.)

S17A
I.3.c
S17C
III.6.f

S 431
S 106

C4

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Scoring Scheme	Sample Answers
✓	1. (a) Remove the fuses (or switch off the circuit breakers) from all the circuits in the main electrical panel, except the one operating the dishwasher.
✓	(b) Note the reading on the electrical energy meter installed for the home.
✓	(c) Operate the dishwasher for a full washing cycle.
✓ ✓	(d) During the hot water cycle measure the temperature of the hot water in the dishwasher and the temperature of the cold water.
✓	(e) Repeat (b) at the end of the cycle.
✓	(f) Replace all the fuses, or switch on the circuit breakers.
✓ ✓ ✓	(g) Calculate the heat energy used to heat the water. (See the manual or the instruction booklet for the amount of water used in a cycle.)
✓	(h) Add the heat energy to the electrical energy to obtain the total energy.

Scoring Scheme	Sample Answers
√ √	2. (a) Connect a wattmeter into the electric dishwasher circuit.
√	(b) Measure the time taken for the electric dishwasher to complete a full cycle.
√	(c) Note the wattmeter reading while the dishwasher is operating.
√ √ √	(d) Calculate the electrical energy used. ($E = Pt$)
√ √ √	(e) Calculate the heat energy used to heat the water (as in procedure 1 above). (See the manual or instruction booklet for the amount of water used in a cycle.)
√	(f) Add the heat energy to the electrical energy.
√√√√√ √√√√√ √	3. Use the same method as solution #2 above, but use a voltmeter and ammeter to measure voltage and current separately, and use $P = VI$ to obtain the power.